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Game of Swarms

Swarm Technologies, Control, and Autonomy in Complex Weapons Systems

Goetz Herrmann / Jutta Weber

> [S]warming may become the key mode of conflict in the information age.[1]

> [A] central aspect of the future of warfare technology is to get networks of machines to operate as self-synchronized war fighting units that can act as complex adaptive systems. […] We want these machines to be fighting units that can operate as reconfigurable swarms that are less mechanical and more organic, less engineered and more grown.[2]

The "New" Hype: Swarm Technologies in Military Development

Over the past years, "swarm intelligence" has become a significant factor in the development of autonomous weapons systems throughout the world. Since at least the early 21st century, the "swarming" of teleoperated drones has already played an important role in military contexts.[3] According to media reports, a first coordinated attack with five teleoperated drones and ten Hellfire missiles was carried out in 2009, during which 17 alleged Taliban fighters were killed.[4] Today military and military-related research institutions and universities in leading industrialized nations are working intensively on swarming algorithms and microrobots. The long-term incentive of this research is to enable the deployment of complex adaptive swarms of autonomous drones.[5] Thus, the US Department of Defense (DoD) announced "one of the most significant tests of autonomous systems"[6] when it released a swarm of 103 Perdix drones from three F/A-18 Super Hornet fighter aircraft into the sky over China Lake in California. "The micro-drones demonstrated advanced swarm behaviors such as

[1] John Arquilla / David F. Ronfeldt: *Networks and Netwars. The Future of Terror, Crime, and Militancy.* Santa Monica: RAND Corporation 2001. http://www.rand.org/pubs/monograph_reports/MR1382.html (accessed: December 18, 2019).
[2] John Sauter qtd. in Jake Kosek: Ecologies of the Empire. On the New Uses of the Honeybee. In: *Cultural Anthropology* 25,4 (2010), pp. 650–678, here p. 667.
[3] Sean J. A. Edwards: *Swarming on the Battlefield. Past, Present, and Future*. Los Angeles: RAND Corporation 2000. https://www.rand.org/pubs/monograph_reports/MR1100.html (Accessed: December 18, 2019); John Arquilla / David F. Ronfeldt: *Swarming and the Future of Conflict*. Santa Monica: RAND Corporation 2000. https://www.rand.org/pubs/documented_briefings/DB311.html (Accessed: December 18, 2019); J.A. / D.F.R.: Network and Netwars; Lashon Booker: Learning from Nature. Applying Biometric Approaches to Military Tactics and Concepts. In: *Edge* 9,1 (2005).
[4] Robert Windrem / Jim Miklaszewski / Mushtaq Yusufzali: Pakistan Officials. U.S. Missile Attacks Kill 17. In: *NBC News*, December 17, 2009. http://www.nbcnews.com/id/34461908/ns/world_news-south_and_central_asia/t/pakistan-officials-us-missile-attacks-kill/ (accessed: April 06, 2020).
[5] Michael Rubenstein / Alejandro Cornejo / Radhika Nagpal: Programmable Self-Assembly in a Thousand-Robot-Swarm. In: *Science* 345,6198 (2014), pp. 795–799.
[6] US Department of Defense (DoD): Department of Defense Announces Successful Micro-Drone Demonstration, January 09, 2017. https://www.defense.gov/Newsroom/Releases/Release/Article/1044811/department-of-defense-announces-successful-micro-drone-demonstration/ (accessed: December 18, 2019).

collective decision-making, adaptive formation flying, and self-healing."[7] In 2017, Chinese developers even reported successful tests with 119 microdrones.[8] The participating China Electronics Technology Group Corporation (CETC) regards swarm intelligence as "the core of artificial intelligence of unmanned systems and the future of intelligent unmanned systems".[9] The great significance of swarm intelligence for the Chinese military is also underscored by the substantial investments in their development.[10] The fact that countries such as Russia and South Korea are also advancing the development of drone swarm technologies can be interpreted as an indication of the vast military strategic potential recognized in these systems.[11]

The debate on autonomously acting and armed drone swarms accompanying this trend is highly ambivalent: on the one hand, the development of fully operational drone swarms is still in its infancy, on the other hand, military-related experts are already talking about the next important 'evolutionary step' toward Lethal Autonomous Weapons Systems (LAWS)[12], and industrialized countries are investing large sums in their development. Although the time and the concrete forms of deployment are still largely unforeseeable, it is not too early to formulate some important questions:

Would autonomously operating drone swarms constitute new forms of human-machine interaction and warfare? "Classic" remote-controlled as well as autonomous drone systems are already extremely complex configurations of the interaction between human and non-human agents. How would these configurations be affected by technological entities and human agents collaborating as a complex system in the context of the given infrastructures?

As flexibility and spontaneous adaptability play an important role in swarming, the problems of complex human-machine connections already discussed in the context of teleoperated drones and individually operating LAWS could intensify. Above all, the deployment of LAWS raises important questions pertaining to society, ethics, and international law. Discussions about autonomy come to mind (how much autonomy do people still have in these human-machine configurations, and how autonomously can or should LAWS operate?), questions of control (who controls behavior in what way and to what extent? What in fact is control (meaningful control!) in a human-machine connection?), and responsibility (how to interpret responsibility in complex sociotechnical systems? At what point can an action be called a decision, and can individual agents be held accountable?).

Interestingly, many of the basic assumptions and concepts currently entering the drone debate are anything but new. The bio-cybernetic foundation of this debate can be traced back to the 1940s.[13] Their powerful epistemological and ontological concepts (of systems analogy, black-boxing of organisms, and questions of emergence and swarming) were central to the development of connectionism in AI, artificial-life research as well as bioinspired and behavior-based robotics. To this

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[7] Ibid.

[8] China Launches Record-breaking Drone Swarm. In: *Xinhua*, June 11, 2017. http://www.xinhuanet.com//english/2017-06/11/c_136356850.htm (accessed: December 18, 2019).

[9] Ibid.

[10] See Elsa Kania: *Battlefield Singularity. Artificial Intelligence, Military Revolution, and China's Future Military Power.* Washington, D.C.: Center for a New American Security 2017, pp. 22–23.

[11] See Zachary Kallenborn / Philipp C. Bleek: Swarming Destruction. Drone Swarms and Chemical, Biological, Radiological, and Nuclear Weapons. In: *The Nonproliferation Review* 25,5–6 (2018), pp. 1–21, here p. 2.

[12] See Paul Scharre: *Army of None. Autonomous Weapons and the Future of War.* New York: Norton 2018, p. 17.

[13] See Ludwig von Bertalanffy: *General System Theory. Foundations, Development, Applications*. New York: Braziller 1968; Jean-François Lyotard: *Das postmoderne Wissen. Ein Bericht*, transl. from the French by Otto Pfersmann. Wien: Passagen 1999; Jutta Weber: *Umkämpfte Bedeutungen. Naturkonzepte im Zeitalter der Technoscience*. Frankfurt am Main: Campus 2003.

day, the latter expresses aspirations to build robots that can adapt to unforeseeable situations,[14] an ability that is also essential for the concepts of autonomous drone swarms.

This development is underscored by socio-theoretical models that have also gained importance in the debate on security politics over the past 20 years: due to the insecurity arising from the enormous complexity of the world, the analytical focus of these models has shifted from individual agents or linear processes to decentralized networks and complex adaptive systems. In dealing with the ensuing demands on security politics – such as a globally conducted "War on Terror" – a key role is attributed to newer technologies. At the same time, technologies such as autonomous or partly autonomous drones are the prerequisite for specific forms of warfare.[15]

Our contribution therefore refrains from discussing the development and potential military deployment of drone swarms as an isolated technological innovation or as a story of teleological progress. Instead swarming must be seen in the context of a broadly conceived epistemological and ontological shift with far-reaching ethical and political implications. In other words: the fact that a progressing departure from atomistic ontologies[16] can also be observed in the military context alongside a clearer focus on dynamic networks and complex self-organized processes and systems, affects the way we perceive, interpret, and understand the world, and thus, act and assess actions. Technology has a deciding impact on the formation of this interpretive framework, which in turn further "ignites" its development.

Hence, it is not only about the prominent question in the debate on autonomous weapons systems, namely "What is 'man's' position in war and how can/should LAWS be controlled?", but also: Which dynamics arise from these new human-machine constellations? How are knowledge and agency produced within them and on which bases? And furthermore: Is human responsibility conceivable in these constellations, and if so, how?

Definition: Swarm Technologies, Autonomous Weapons Systems, and Control

A swarm is classified as a decentralized synergy between different entities whose complex and synchronous behavior enables the accomplishment of a common goal. Swarms are characterized by the individual components' ability to communicate with one another, and thereby, to adapt and change their behavior to suit the situation at hand. Attributed to nature by researchers, these behavior patterns have been summarized as "swarm intelligence" for some years, and attempts have been made to harness this phenomenon for AI research. Primarily "social insects", such as ants, termites, wasps, and bees, but also birds and fish, serve as sources of inspiration. Their ability to solve complex tasks with relatively simple actions and "self-organization" (e.g. nest building) without need of a central supervisory body has sparked great interest.[17]

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[14] See Weber: *Umkämpfte Bedeutungen*; Lucy Suchman / Jutta Weber: Human-Machine Autonomies. In: Nehal Bhuta / Susanne Beck / Robin Geiß / Hin-Yan Liu / Claus Kreß (eds): *Autonomous Weapons Systems. Law, Ethics, Policy*. Cambridge: Cambridge UP 2016, pp. 75–100.

[15] See Derek Gregory: Drone Geographies. In: *Radical Philosophy* 18 (2014), pp. 7–19; Antoine Bousquet: Cyberneticizing the American War Machine. Science and Computers in the Cold War. In: *Cold War History* 8,1 (2008), pp. 77–102; Ian G. R. Shaw: *Predator Empire. Drone Warfare and Full Spectrum Dominance*. Minneapolis / London: U of Minnesota P 2016.

[16] See Mark Coeckelbergh: From Killer Machines to Doctrines and Swarms, or Why Ethics of Military Robotics Is Not (Necessarily) About Robots. In: *Philosophy & Technology* 24,3 (2011), pp. 269–278.

[17] See Christopher G. Langton: Artificial Life. In: Margaret A. Boden (ed.): *The Philosophy of Artificial Life.* Oxford / New York: Oxford UP 1996, pp. 39–94; Christian Blum / Xiaodong Li: Swarm Intelligence in Optimization. In: Christian Blum / Daniel Merkle (eds): *Swarm Intelligence. Introduction and Applications*. Berlin / Heidelberg: Springer 2008, pp. 43–85, here p. 43.

The military and weapons industry also hope to reach a new level of flexibility and cognitive performance in robotic weapons systems through the transference of observations gleaned from nature.[18] As William Roper, director of the Strategic Capabilities Office, which is involved in the development of the abovementioned Perdix microdrones for the DoD, recently underlined:

> Due to the complex nature of combat, Perdix are not pre-programmed synchronized individuals, they are a *collective organism*, sharing one *distributed brain for decision-making* and adapting to each other like swarms in nature […]. Because every Perdix communicates and collaborates with every other Perdix, the swarm has no leader and can gracefully *adapt* to drones entering or exiting the team.[19]

According to this characterization, behavior that is analogous to nature is supposed to enable a *new quality of autonomy* in LAWS, and thus, unrivaled superiority on the battlefield. Some experts even predict that previous methods of warfare could soon become obsolete insofar as interconnected, cooperating swarms of unmanned systems could potentially exceed the cognitive abilities of human agents in certain areas, for instance, by displaying considerably faster response times and thereby accelerating decision making processes significantly.[20] Since there would be either no or decidedly less need to communicate with a central control station, autonomously operating swarms would not only make quicker decisions but also be harder for the opposing side to detect.[21] Moreover, the sheer mass of rapidly and simultaneously operating swarm components is supposed to contribute to overwhelming the opponent's capacity to react. However, this also applies to the initiator's "own" side: it would be cognitively impossible for a human control unit to keep track of such a complex system. For a swarm to operate in this capacity, it must be autonomous, and human control of the individual elements would be virtually impossible.[22]

The difficulty of controlling drone swarms becomes evident in a catchword that keeps resurfacing in the discourse: *emergence*. While superior cognitive abilities have served supporters as an argument for LAWS (and automatization in general) for some time, the capacity for *decentral emergent coordination* has been emphasized as the distinguishing element in swarm intelligence. Thus, each member of the swarm responds to the behavior of the others in its direct proximity without having to take a "detour" via a central coordinating entity.[23] This would enable a swarm as a *whole* to display far more complex behavior than individual elements (drones and platforms) or centrally steered units/troops.[24] In this case, highly complex behavior results from the interaction of relatively simple entities that follow basic rule sets and can therefore adapt to the conditions in their direct surroundings spontaneously and flexibly – this is the adaptability Roper, as quoted above, is referring to when he suggests that drone swarms are not "pre-programmed". A study commissioned by the DoD explains the phenomenon as follows:

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[18] Arquilla / Ronfeldt: Swarming and the Future of Conflict; Kosek: Ecologies of the Empire.

[19] DoD: Department of Defense Announces Successful Micro-Drone Demonstration (emphasis added).

[20] See Robert O. Work / Shawn Brimley: *20YY. Preparing for War in the Robotic Age*. Washington: Center for a New American Security 2014, p. 29; Paul Scharre: *Robotics on the Battlefield, Part II: The Coming Swarm*. Washington: Center for a New American Security 2014. https://s3.amazonaws.com/files.cnas.org/documents/CNAS_TheComingSwarm_Scharre (accessed: April 13, 2019), p. 10.

[21] See Jürgen Altmann: Autonomous Weapon Systems. Dangers and Need for an International Prohibition. In: Christoph Benzmüller / 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, here pp. 3–4.

[22] See ibid., p. 4.

[23] See Scharre: *Army of None*, pp. 19–20.

[24] See Kallenborn / Bleek: Swarming Destruction; Scharre: *Army of None*, pp. 19–20.

> […] the simple rules followed by individual insects give rise to emergent behaviors, i.e., the collective behavior is different than that exhibited by the individuals. The collective behavior of an emergent system can depend strongly on the environmental conditions, even when the basic rule set followed by individual members is essentially constant. In principle, emergent behavior could lead to highly adaptive military systems.[25]

The swarm's higher *reaction speed*, increased level of *autonomy*, and greater *adaptability* to a complex environment as an "emergent, coherent whole"[26] are also mentioned as deciding advantages in an array of other analyses by military strategists.[27] This approach draws on a hypothesis derived from complexity theory according to which complex systems are also capable of changing through adaptation – in other words, learning from experience.

This fascination for adaptability and self-monitoring serves as a compelling illustration of the abovementioned problem of controlling LAWS: presuming that drones really were to be equipped with an AI-based, emergent rule set with the ability to flexibly adapt to situations, the relationship between operator and drone(s) could hardly be qualified as one of causal control. Their behavior would not be transparent and almost impossible to anticipate.[28] The authors of the abovementioned study of the Defense Science Board seem to agree:

> However, predicting collective behaviors 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.[29]

The DoD attempted to invalidate concerns along these lines by emphasizing that

> the department's conception of the future battle network is one where *humans will always be in the loop*. Machines and the autonomous systems being developed by the DoD, such as the micro-drones, will *empower humans to make better decisions faster.*[30]

Before the Hype: Emergence, Self-Monitoring, and Control in Complex Systems – A Trending Topic Rooted in the History of Knowledge

The technosolutionism expressed in this formulation – in other words, the notion of solving complex social issues with simple technical means (and ultimately "empowering" people) – can hardly belie the debates about autonomy and agency in human-machine relationships that have been smoldering for some time. The dream of complex, decentralized systems capable of emergent behavior that is unforeseeable but adaptive and can solve problems that are impossible to program *top-down* was already dreamed in cybernetics, but above all, in newer AI and robotics. In the 1980s, artificial-life research focused on questions of self-organization in nonlinear, open systems and oriented these

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[25] Defense Science Board: *Report of the Defense Science Board Summer Study on Autonomy*. Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics 2016, p. 84.

[26] Scharre: *Robotics on the Battlefield, Part II*, p. 24.

[27] See Defense Science Board: *Report of the Defense Science Board Summer Study on Autonomy*, p. 84; Planungsamt der Bundeswehr, Dezernat Zukunftsanalyse: *Weiterentwicklungen in der Robotik durch Künstliche Intelligenz und Nanotechnologie. Welche Herausforderungen und Chancen erwarten uns? Future Topic*. Berlin: Planungsamt der Bundeswehr, Dezernat Zukunftsanalyse 2013, p. 9; US Air Force: *Small Unmanned Aircraft Systems (SUAS) Flight Plan 2016–2036*. Washington: Deputy Chief of Staff for Intelligence, Surveillance and Reconnaissance (ISR), Office of Primary Responsibility (OPR): AF/A2CU, Remotely Piloted Aircraft (RPA) Capabilities 2016. https://www.af.mil/Portals/1/documents/isr/Small_UAS_Flight_Plan_2016_to_2036.pdf (accessed: December 18, 2019), pp. 12–13.

[28] See Scharre: *Robotics on the Battlefield, Part II*, p. 26.

[29] Defense Science Board: *Report of the Defense Science Board Summer Study on Autonomy*, p. 84.

[30] Ibid. (emphasis added).

examinations toward the theory of nonlinear systems, fuzzy logic, and fractal geometry. Neural networks and simultaneous computers were used as a basis to evoke or simulate emergent systems. These attempts were not primarily geared toward causality and linearity, but rather on formulating fringe conditions for emergence and learning processes, and on simulating "intuition". Processes of tinkering and trial-and-error played a key role.[31] Through the infinite recombination of code sequences, emergence is supposed to lead to qualitative advances in artificial systems (e.g. on the basis of genetic algorithms), and thus, pave the way for the development of autonomous artificial systems capable of learning. Some of the earliest attempts to recreate or even "discover" natural behavior in artificial structures date back to the mathematician and physicist John von Neumann, who developed theoretical models of self-reproducing, cellular automats in the 1940s. In the late 1960s, John Conway also derived his popular computer game *Life* from this idea. The simulation of flocks of birds created by the artificial lifer Craig Reynolds in the late 1980s is another example.

Like traditional AI, this behavior-based approach draws on self-organization, system, and information theory. However, the aim is not only to describe the recursive loops of the self-organization processes of closed systems, but also to operationalize the spontaneous formation of the new in nonlinear, dynamic systems.[32] Hence, the great interest in emergence, which is interpreted as a phenomenon with the capacity to show that "within a structured system, new qualities on higher levels of integration develop which cannot be derived from the knowledge of components on lower levels"[33]. According to the underlying ontological premise, this complex behavior adheres to a few simple rules that can be simulated in technological systems. While linear systems are studied by isolating and analyzing the individual components to understand the whole, the aim is now to explore the interaction and behavior of the individual components amongst each another to understand the system and its behavior as a whole.[34] The "disturbance" (of the self-organization) of a system through noise is reinterpreted as a potential impetus for the evolvement of something new, for higher development and complexity. In this context, the self-organization of artificial or organic systems is perceived as a pattern, a constellation of patterns with the potential to change: "The category of becoming, of possibility, of spontaneity is becoming conceivable for the logic of technology sciences."[35] Emergence can thus be reinterpreted as information-theoretic patterns that can only be assessed and reconstructed on a probabilistic basis. On the other hand, the multiplication and crossing of simple rules and mechanisms is supposed to generate complex behavior. However, this approach also nurtures doubts as to whether the construction of these complex systems with their emergent behavior can be analyzed and controlled comprehensively. It is no coincidence that the roboticist Rodney Brooks, an early advocate of the emergent approach, describes his robots as not only "fast" and "cheap", but also "out of control".[36]

Evidently, the shift in the epistemological and ontological principles of AI – e.g. the concentration on emergent behavior, spontaneity, tinkering, and unpredictability as well as the (partial) departure from causality and linearity – has made human-machine connections more opaque and questions of

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[31] Weber: *Umkämpfte Bedeutungen.*
[32] See Katherine N. Hayles: *How We Became Posthuman. Virtual Bodies in Cybernetics, Literature and Informatics*. Chicago: U of Chicago P 1999, p. 222.
[33] Ernst Mayr: *Das ist Biologie: die Wissenschaft des Lebens*. Heidelberg / Berlin: Springer 1998, p. 42.
[34] See Langton: Artificial Life, p. 53.
[35] Weber: *Umkämpfte Bedeutungen*, p. 201.
[36] Rodney A. Brooks / Anita M. Flynn: Fast, Cheap and out of Control. A Robot Invasion of the Solar System. In: *Journal of the British Interplanetary Society* 42 (1989), pp. 478–485.

autonomy more complex since at least the 1980s.[37] While agency has never been solitary, it is becoming even more complex in the current human-machine structures.

Complex Systems, Networks, and Swarms in the Security Discourse

The previous observations about the connection between current trends in military robotics and historical precursors show that an isolated examination of an individual technology and its "innovative potential" and "performance capacity" is not enough – to understand their function within a social structure, technological developments should always be placed in a wider historical and socio-cultural context. More than just a means to an end, they have a deciding impact on the formation of social processes (or human-machine interactions) within a complex interdependence. This ability to constitute reality is especially consequential in the case of military robotics since they are not developed and employed in a political vacuum: the question is thus, why LAWS – now even in the shape of autonomous drone swarms – have become interesting for parts of the military and the political sphere. And: How the use of nonlinear methods affects the (non-)compliance with the guidelines of international law.

A look at the discourse surrounding LAWS and swarming in the military and in security politics is helpful for further elaborations on this idea. The growing significance of swarming in the military's strategic considerations is a process which is taking place against the backdrop of a profound shift in the approach to security politics: while social ontologies derived from network and systems theory have defined the debate in cultural and social sciences for some time, analyses pertaining to security politics also started to draw increasingly on the theories of more complex systems in the 1990s.[38] During this time, prominent researchers from the field of International Relations, such as James N. Rosenau, popularized the import of concepts and terms from complexity theory, such as "human systems"[39], which also describe a tendency toward self-organization on the level of international politics, or regard international organizations as "complex adaptive systems"[40] with "emergent properties"[41].[42] From here, similar ideas also found their way into the mainstream discourse on international and security politics. Over the course of the debate on globalization, influential global governance and human

[37] See also Suchman / Weber: Human-Machine Autonomies.

[38] See Philip Bobbit: *Terror and Consent. The Wars for the Twenty-First Century*. London: Penguin 2013; Antoine Bousquet: Complexity Theory and the War on Terror. Understanding the Self-Organising Dynamics of Leaderless Jihad. In: *Journal of International Relations and Development* 15,3 (2012), pp. 345–369; A.B. / Simon Curtis: Beyond Models and Metaphors. Complexity Theory, Systems Thinking and International Relations. In: *Cambridge Review of International Affairs* 24,1 (2011), pp. 43–62; Melinda Cooper: Pre-empting Emergence. The Biological Turn in the War on Terror. In: *Theory, Culture & Society* 23,4 (2006), pp. 113–135; Michael Dillon: Underwriting Security. In: *Security Dialogue* 39,2–3 (2008), pp. 309–332; Goetz Herrmann: *Reflexive Sicherheit, Freiheit und Grenzmanagement in der Europäischen Union.* Wiesbaden: Springer 2018; Brian Massumi: National Enterprise Emergency. Steps Toward an Ecology of Powers. In: *Theory, Culture & Society* 26,6 (2009), pp. 153–185; James N. Rosenau: Many Damn Things Simultaneously – at Least for Awhile: Complexity Theory and World Affairs. In: *Theoria. A Journal of Social and Political Theory* 94 (1999), pp. 48–66.

[39] Rosenau: Many Damn Things Simultaneously.

[40] Ibid., p.54.

[41] Ibid.

[42] According to this understanding, international organizations also evolve through the participating agents' self-regulating behavior and thereby develop new qualities. As a result, these organizations are relatively stable, albeit not fixed and are subject to ongoing adaptative dynamics and change: "Thus, for example, the NATO of 1996 is very different from the NATO of 1949 and doubtless will be different from the NATO of 2006, but its emergent properties have not transformed it into an entirely new organization. Rather, its internal dynamic has allowed it to adapt to change even though it is still in fundamental respects with the North Atlantic Treaty Organization." (Rosenau: Many Damn Things Simultaneously, p. 55.)

security concepts have drawn on this idea[43] by interpreting the world as a global network made up of complex transnational interrelations and circulatory movements, in which the modern nation state is merely a subcomponent and no longer the only setting and starting point for political interventions.[44] According to this train of thought, the "globalized" world in its current state is determined by a threatening level of uncertainty insofar as spontaneous and nonlinear processes of *change* and *adaptation* are always possible through the linking of contingent chains of events, which can also lead to dangers relevant to security.[45] As the prominent example of transnational terror networks[46] (such as al-Qaida) shows, *emergence* is also key to understanding them insofar as their structure and mode of operation can be described as "*nonlinear phenomena* and bottom-up processes of *emergent self-organization*"[47].

According to Sean Lawson[48], the fact that these metaphors and concomitant ontological shifts are also gaining ground on the level of US military planning results from the *appropriation* of concepts developed in nonlinear science and theories of complex systems by military personnel and civilian defense experts in the 1990s, whose influence spread to the highest government offices from the turn of the millennium onwards.[49] With the end of the Cold War, battlefields were also regarded as *nonlinear* and *chaotic* spaces determined by speed and offensive strength, which led those responsible for the orientation of military doctrine to rethink their theoretical principles. References to popular publications from the field of nonlinear science provided "a patina of scientific legitimacy"[50] and had a decisive impact on the restructuring of the US military. For the latter, it became important to mirror the complexity and fluidity of the world in its own structures and practices.[51]

The aim was to strengthen adaptability by dispensing with rigidly hierarchical and centralistic control concepts, thereby enabling prompt and adequate reactions and actions on different levels. From the beginning, a key role was ascribed to the newest information and communication technologies.[52] Network Centric Warfare (NCW), a concept that emerged in the 1990s, is probably the most prominent result of this process. Especially the first systematic formulations refer explicitly to premises based on complexity theory[53]: decentralized communication between individual action forces and the self-organization of small units define the approach. The comprehensive interconnection of sensors, command posts, and weapons systems with the aid of modern information and communication technologies is supposed to establish an "information advantage" over the enemy. This provides the

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[43] See Mark Duffield: *Development, Security and Unending War. Governing the World of Peoples*. Cambridge: Polity 2007, pp. 111–132; Mary Kaldor: *Human Security. Reflections on Globalization and Intervention*. Cambridge: Polity 2007, pp. 159–160.

[44] See Brad Evans: *Liberal Terror.* Oxford: Wiley 2013, p. 35; Herrmann: *Reflexive Sicherheit, Freiheit und Grenzmanagement in der Europäischen Union*, pp. 51–55.

[45] See Bobbit: *Terror and Consent.*

[46] Besides terror networks, pandemics (see Cooper: Pre-empting Emergence), fragile states, migration movements, or natural catastrophes are also mentioned.

[47] Bousquet: Complexity Theory and the War on Terror, p. 349 (emphasis added).

[48] Sean Lawson: Surfing on the Edge of Chaos. Nonlinear Science and the Emergence of a Doctrine of Preventive War in the US. In: *Social Studies of Science* 41 (2011), pp. 563–584.

[49] Under George W. Bush, advocates of a decidedly military perspective were given influential positions in the US DoD. Lawson underscores the roles of Arthur K. Cebrowski and Thomas Barnett, who were to have a defining impact on the concept of preemptive warfare (see Lawson: Surfing on the Edge of Chaos, pp. 570–576).

[50] Ibid., p. 566.

[51] See ibid., p. 571.

[52] See David S. Alberts / John J. Garstka / Frederick P. Stein: *Network Centrik Warfare. Developing and Leveraging Information Superiority*. Washington, DC: National Defense University 1999, p. 15.

[53] See ibid.; James Moffat: *Complexity Theory and Network Centric Warfare.* Washington, DC: National Defense University 2003.

individual units within the troop with precise knowledge of the events on the battlefield enabling them to act faster and to adapt more flexibly without central organization. The declared goal of NCW is "full spectrum dominance"[54], in other words, overall control on all operational levels. The fact that outer space, the electromagnetic level, and "cyberspace" are also mentioned[55] besides the three classic areas land, sea, and air, manifests the great significance of the *global technological infrastructure and interconnection* this would necessitate – an important prerequisite for the subsequent expansive military deployment of drones.

The concomitant *blurring of previous categories, duties, and spatial concepts within security politics* is equally significant. Hence, the lines between different political and deployment areas become increasingly ambiguous (e.g. civilian/military in the field of peacekeeping, which is in turn associated with development politics and disaster prevention). The sites of the conflicts themselves, however, are also redefined in accordance with network theory. The leading authors in the development of NCW, David S. Alberts, John J. Garstka, and Frederick P. Stein use the term "battlespace" to exemplify this phenomenon: "The term battlespace recently replaced battlefield to convey a sense that the mission environment or competitive space encompasses far more than a contiguous physical space."[56] The radicality of this redefinition of the concept of space is not to be underestimated and manifests the ontological change mentioned in the introduction and summarized by Marc Coeckelbergh as follows:

> In military technological thinking and research, atomistic ontologies are being replaced by thinking in terms of systems, networks, and swarms. In a network, (military) activity is not about single, atomistic agents exercising their agency in single actions. Instead, agency (if this is still the adequate term at all) is distributed, collective, and emergent. It cannot be reduced to the level of the parts […], nodes […], or – why not – 'bees' […]. None of the parts, nodes, or bees control the action […], but the system, network, or swarm as a whole acts.[57]

Drone Wars

This ontological change in warfare is the foundation from which the current debates on LAWS and swarming proceed. Ian Shaw[58] also identifies swarming as a further development of the NCW concept, in which a shift from "network-space" (as expressed in the abovementioned term "battlespace") to "swarm-space" can be observed[59]. As he explains, the focus is once again on mass:

> The return to mass as a medium of military power is, however, different from the past. Mass in the 21st century requires a *molecular* and *plastic* robotic mass: one that mirrors the swarms of bees, fish, ants, and birds in the natural world. Swarming thus materializes a nonlinear swarm-space: a massed atmospheric attack. Targets are secured and overwhelmed by intelligent drones acting and moving faster than humans. This shifts the battle-regime from the surfaces of land power and the skies of air power, to the swarm-spaces of robot power, crystallizing a volumetric and multidimensional geometry of violence. This upturns the spatial pointillism and logic of human control in current drone warfare.[60]

Although this analysis is still partly speculative, other authors have also made direct connections between NCW and swarm concepts. An early example can be found in a prominent report for the

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[54] US Department of Defense (DoD): *Joint Vision 2020*, June 2000. http://www.pipr.co.uk/wp-content/uploads/2014/07/jv2020-2.pdf (accessed: December 18, 2019).
[55] Ibid., p.6.
[56] Alberts / Garstka / Stein: *Network Centrik Warfare*, p. 60.
[57] Coeckelbergh: From Killer Machines to Doctrines and Swarms, p. 6.
[58] Ian G. R. Shaw: Robot Wars. US Empire and Geopolitics in the Robotic Age. In: *Security Dialogue* 48,5 (2017), pp. 451–470.
[59] Ibid., p. 459.
[60] Ibid., p. 460 (emphasis in original).

RAND Corporation by John Arquilla and David Ronfeldt.[61] The influential military strategists predicted that "swarming will likely be the future of conflict"[62]. At this point, they express a still rather general understanding of swarming as a form of battle that relies on "systematic pulsing and force and/or fire by dispersed, internetted units"[63] in order to attack the enemy from all sides – in essence, an approach with a long history. Here too, the aim is to enable a decentralized coordination of dispersed units and to overwhelm enemies, e.g. by confronting them not with a coherent formation, but with a conglomerate of targets that appear to be both everywhere and nowhere.[64] According to the authors, this makes swarming superior to other military tactics, such as "maneuvering"[65], but requires more elaborate coordination and communication. The important function of modern communication technology is thus further inscribed into military thought and the shift in an ontology of war consistently promoted. Newer swarm concepts with a focus on the deployment of drones or autonomous weapons systems are linked directly to these hypotheses.[66] The problems that could arise from a probabilistically functioning coordination of entities, not only for the military but also in terms of international law, are not mentioned.

Although this evolvement can be explained by new technological developments, it is also linked to the specifics of the asymmetrical conflict situations which increasingly became the focus of military strategic considerations around the turn of the millennium. This means that the technologies applied in this process are not only instruments for the implementation of a new strategic orientation; they also have a defining impact on the formulation and further development of military doctrines. The "War on Terror" serves as an especially compelling example. The detection and targeted killing of terrorists/insurgents (and thereby also the determination of non-combatants in a complex environment) is the main component of this asymmetrical form of conflict, which is mostly carried out in postcolonial arenas. The necessary surveillance technology is successively based on the deployment of teleoperated – and partly armed – drones (for the ongoing surveillance of the terrain or individuals) in connection with an increasingly extensive infrastructure of data bases and their algorithmically supported evaluation. In this respect, the development of new military "possibilities" (targeted killing via drones) is not only conveyed by technology, it also informs notions of legitimate application of violence: Who or what is regarded as a legitimate target, and how is the act of killing experienced and evaluated in ethical and political terms? Elke Schwarz uses targeted killings via teleoperated drones to exemplify these dilemmas[67]: Described by their advocates as "more ethical" (since they are targeted), she locates this version of killing in a biopolitical hygiene discourse:

> Drones enable the (de)politicization of targets by abstracting human life into a techno-political entity that can be captured in clinical terms as data, typically through new visualization techniques. In such a context, targeted killing practices come to reflect a logic of biopolitical power in which logistical decisions and arithmetic calculations turn political violence into a form of risk management.[68]

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[61] Arquilla / Ronfeldt: Swarming and the Future of Conflict.
[62] Ibid., p. 5.
[63] Ibid., p. 8.
[64] See Scharre: *Robotics on the Battlefield, Part II*, p. 29.
[65] Ibid.
[66] See Defense Science Board: *Report of the Defense Science Board Summer Study on Autonomy*; Kallenborn / Bleek: Swarming Destruction, p. 2; Scharre: *Robotics on the Battlefield, Part II*, p. 24.
[67] See Elke Schwarz: Prescription Drones. On the Techno-Biopolitical Regimes of Contemporary 'Ethical Killing'. In: *Security Dialogue* 47,1 (2015), pp. 59–75.
[68] Ibid., p. 61.

In this context, the extent of the reality-constitutive involvement of technologies is also demonstrated by the emergence of so-called kill lists: they are generated by accessing flexible data bases for the purpose of the identification and targeted killing of individuals.[69] Enabled by new technological developments (big data), the quantitative methodology of network analysis helps to identify dangerous subjects according to behavior patterns. A process of target selection (terrorist/non-terrorist) based on correlation has thus replaced the previously dominant cause-effect principle as a means of defining threats.[70] However, by treating the thusly generated categories and structures as neutral and objective, the agents contribute to an objectification of results based on undeniably controversial premises. In this way, they become incorporated in concrete political practice – for instance, when the US government relies on the validity of the processes that choose targets "worthy of killing". At the same time, they impact cognition processes that influence perception, attitudes, and feelings – in this case, the perception and definition of threats. Although the "decision" to carry out the deadly attack is made by a human being (sometimes even the US president), it is an extremely complex cognitive performance involving different human and non-human/mechanical agents, which makes a simple attribution of tasks difficult and can hardly be described as meaningful human control.

Conclusion

As these examples show, that which could be described as the concept of a sovereign and intentionalist subject has undergone an increasing erosion on the battlefield over the past years. Although this idea was already more fiction than reality in the first two World Wars, the development of autonomous weapons systems clearly underscores the problem. Target formulation – or rather, the control of behavior – depends on the diverse components and processes in complex structures. This makes the question of individual control through individual human subjects extremely complicated. The deployment of autonomous drone *swarms* would further complicate the problem if behavior were to be reduced to emergent "adaptation effects". This would mean the end of fixed/preformulated targets in a static area. Targets would forever follow dynamically "emergent" adaptation logics. Besides considering whether these systems could "accidentally" attack their own troops – a question the military itself is at least willing to ask – it must be clearly underscored that the deployment of "learning" systems (unsupervised learning) in these mortal contexts is irresponsible. The decision to test autonomous vehicles in a real-life experiment[71] was already more than questionable[72] and resulted in many deaths. Only cynics would regard training swarms of killer robots at the cost of human lives as a valid option.

This calls for a new conception of responsibility that is not based on a classic (in philosophical terms "transcendentally humanist") understanding of the subject, as is the case in many ethical, political, and legal discourses, but accepts the challenge of human-machine assemblages instead of focusing solely on individuals and their respective moral power of judgement.

In the late 1980s, Ulrich Beck already identified the inadequacy of these concepts in his analysis of the risk society and spoke of (publicly) "organized irresponsibility"[73] with a view to large socio-technical

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[69] See Jutta Weber: Keep Adding. On Kill Lists, Drone Warfare and the Politics of Databases. In: *Environment Planning D: Society and Space* 34,1 (2015), pp. 107–125.

[70] See ibid., p. 7

[71] Wolfgang Krohn / Johannes Weyer: Die Erzeugung sozialer Risiken durch experimentelle Forschung. In: *Soziale Welt* 40,3 (1989), pp. 349–373.

[72] Cordula Kropp: *Autonomes Fahren. (Vertrauen in) Technostrukturen in der Betaphase.* Unpublished manuscript 2019.

[73] Ulrich Beck: *Gegengifte. Die organsierte Unverantwortlichkeit*. Frankfurt am Main: Suhrkamp 1988, pp. 96–112.

systems. In 1984, Charles Perrow referred to the inherent risks of large-scale technology, the miniaturization of the dangers by those in charge, and the utterly inappropriate shifting of responsibility onto individual agents in his book *Normal Accidents*. Wolfgang Krohn and Johannes Weyer drew attention to the problems arising from real-life experiments, such as the release of genetically modified plants. The newer human-machine assemblages are extremely complex and defined by an especially close linking of humans and machines (also in the case of emergent swarms). Some speak of shared agency, and the leading question is whether a so-called meaningful control of these systems through human beings is even possible anymore. As described above, doubts about the applicability of this approach to complex, large-scale technological systems were already expressed in the 1980s.

Against this backdrop, an atomistic perspective is not maintainable. Instead the "big picture" must be taken into consideration to understand the consequences emerging from actions enabled by the overall structure.[74] In other words: a considerably more critical approach to the structural connections is necessary. This would include not only the people involved (e.g. military personnel with their respective command structures, engineers, legal experts, insurgent fighters etc.), the technological components, and the structure of human-machine assemblages, but also their specific embedding in global power structures and rationalities, which – in this case – goes hand in hand with a specific form of warfare. As already mentioned, it is surely no coincidence that an overwhelming number of drone deployments occur in the context of asymmetrical or imperial conflicts. In this respect, it seems almost cynical to insist on individual autonomy (in isolated actions) as a basis for moral agency[75] – criticism can in fact only be aimed at a social context "that goes beyond the existence of individual human beings"[76]. Thus, shifting the (alleged) responsibility for "technological thinking" to individuals does not serve as a sufficiently critical position. As explained above, the perception and significance of "life", "value", and threat is already predisposed through a historically specific biopolitical[77] and techno-rational[78] logic of utilization that far exceeds any individual's capacity for decision-making and comprehension.

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[74] See N. Katherine Hayles: *Unthought. The Power of the Cognitive Nonconscious.* Chicago / London: U of Chicago P 2017, p. 36.

[75] See Human Rights Watch: Killer Robots and the Concept of Meaningful Human Control. Memorandum to Convention on Conventional Weapons (CCW) Delegates. In: *Human Rights Watch*, April 2016. https://www.hrw.org/sites/default/files/supporting_resources/robots_meaningful_human_control_final.pdf (accessed: December 18, 2019).

[76] Theodor W. Adorno: Vorlesungen zur Einleitung in die Erkenntnistheorie, 1957, qtd. in Jürgen Ritsert: Gesellschaft. Ein unergründlicher Grundbegriff der Soziologie. Frankfurt am Main: Campus 2000, p. 14.

[77] See Schwarz: Prescription Drones; Michael Dillon / Julian Reid: *The Liberal Way of War. Killing to Make Life Live*. London / New York: Routledge 2009

[78] Weber: Keep Adding.