CENTRE FOR MILITARY STUDIES
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In, On, or Out of the Loop?

Denmark and Autonomous Weapon Systems

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Denne rapport er en del af Center for Militære Studiers forskningsbaserede myndighedsbetjening for Forsvarsministeriet og de politiske partier bag forsvarsforliget. Formålet med rapporten er at give en begrebsmæssig ramme til at forstå de unikke egenskaber ved våben, der i stigende grad er i stand til at udføre funktioner autonomt – dvs. uden direkte menneskelig kontrol – samt at diskutere det potentielle politiske dilemma forbundet med at opretholde en meningsfuld menneskelig kontrol over sådanne våbens brug og funktion.

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This report is a part of Centre for Military Studies' policy research services for the Ministry of Defence and the political parties to the Defence Agreement. The purpose of the report is to provide a conceptual framework for understanding the unique characteristics of weapons that are increasingly able to perform functions autonomously – i.e., beyond direct human control – as well as to frame the potential policy dilemma of maintaining meaningful human control over the use and functioning of these weapons.

The Centre for Military Studies is a research centre at the Department of Political Science at the University of Copenhagen. The Centre undertakes research on security and defence issues as well as military strategy. This research constitutes the foundation for the policy research services that the Centre provides for the Ministry of Defence and the political parties to the Defence Agreement.

This report contains an analysis based on academic research methodology. Its conclusions should not be understood as a reflection of the views and opinions of the Danish Government, the Danish Armed Forces or any other authority.

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English Abstract

The increasing ability of military weapon systems to perform functions autonomously is a strategic trend with implications for defence policies and warfare in general. Denmark and many of its allies possess weapons that function in an automatic, automated, or autonomous manner – the difference being the degree of sophistication of weapon responses to external stimuli. Such weapons can be controlled directly with a "man-in-the-loop," managed by a "man-on-the-loop," or supervised by a "man-out-of-the-loop." Although all uses of force by Western militaries take place within an institutionalised process that ensures the lawful application of violence, the challenge for policy is to develop technological systems and institutions whose procedures and command structures maintain meaningful human control over these autonomously functioning weapon systems, particularly with regard to the functions of selecting and engaging targets with lethal violence. Like most other advanced democracies, Denmark has not developed a comprehensive policy with regard to weapon systems with autonomous functions. We suggest that Danish decision-makers consider adopting a defence planning mechanism to analyse the issue of autonomous systems and clarify matters of principle and general Danish policy. The topics to be addressed could include a process to consider the acquisition, integration, and utilisation of weapon systems with autonomous functions, including appropriate command and control arrangements.

Dansk resumé

Militære våbensystemers stigende evne til at udføre funktioner autonomt, er en strategisk udvikling med konsekvenser for krigsførelse generelt og for forsvarspolitik i Danmark. Ligesom mange af dets allierede besidder Danmark våben, der fungerer automatisk, automatiseret, eller autonomt – forskellen ligger i perfektioneringen af våbensystemernes reaktion på stimuli. Endvidere kan sådanne våben kontrolleres direkte af en *man-in-the-loop*, styres af en *man-on-the-loop*, eller overvåges af en *man-out-of-the-loop*. Selvom vestlige militære styrkers brug af væbnet magt foregår i en institutionaliseret proces der sikrer lovlig voldsudøvelse, er udfordringen for policy-udviklingen på området at udvikle teknologisystemer og institutioner hvis procedurer og kommandostrukturer opretholder meningsfuld menneskelig kontrol over autonome våbensystemer, især med henblik på udvælgelsen af mål for dødbringende angreb. Ligesom de fleste andre demokratiske lande, har Danmark endnu ikke udviklet en omfattende politik på området for autonome våbensystemer. Vi foreslår, at danske beslutningstagere overvejer at vedtage en forsvarsplanlægningsmekanisme til at analysere spørgsmålet om brugen af autonome våbensystemer, samt afklare principielle og generelle problemstillinger for dansk politik på området. Emner der er værd at overveje omfatter en proces der udstikker en retning for anskaffelse, integration og brug af våbensystemer med autonome funktioner, samt spørgsmålet om kommando- og kontrolarrangementer på området.

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1. Introduction

The ability of machines to act in the absence of human control has increased dramatically over the course of the past decade. Machines can increasingly sense their environment, discriminate between aspects of it, determine behaviour based on these sensory inputs, and act without human involvement. The use of such machines in public and private, civilian and military activities raises significant practical, political, policy, commercial, industrial, ethical, moral, and legal issues. This is especially the case with machines that autonomously facilitate or conduct violence – i.e., weapon systems. This trend therefore impacts military affairs as well as other areas of human endeavour.

Weapon systems that are capable of functioning autonomously may be seen to possess a certain allure and mystique. They can provide a remote presence and undertake tasks that are too dirty, dull, or dangerous for human beings. They promise to reduce costs, casualties, and collateral damage while increasing military effectiveness, efficiency, and efficacy. Systems with autonomous capabilities will become increasingly prevalent in civilian and military applications. They are progressively being incorporated into Western military forces,[1] including those of Denmark, and will also be adopted by adversaries in the future. Weapon systems with autonomous functions will likely become a permanent feature of military forces and their operations.

These developments have caused serious alarm in some quarters.[2] Many fear that countries will acquire weapon systems with autonomous functions – particularly to select and engage targets with destructive force – to address tactical and operational problems on the battlefield while losing sight of the inherent dangers that such solutions create. As the "Campaign to Stop Killer Robots" characterises the problem,

> Allowing life or death decisions to be made by machines crosses a fundamental moral line. Autonomous robots would lack human judgment and the ability to understand context. These qualities are necessary to make complex ethical choices on a dynamic battlefield, to distinguish adequately between soldiers and civilians, and to evaluate the proportionality of an attack. As a result, fully autonomous weapons would not meet the requirements of the laws of war.[3]

Furthermore, many – including physicist Stephen Hawking and entrepreneur Elon Musk – fear the proliferation of these weapons.[4]

> [T]he endpoint of this technological trajectory is obvious: autonomous weapons will become the Kalashnikovs of tomorrow … ubiquitous and cheap for all significant military powers to mass-produce. It will only be a matter of time until they appear on the black market and in the hands of terrorists, dictators wishing to better control their populace, warlords wishing to perpetrate ethnic cleansing, etc.[5]

They therefore propose banning the development of "offensive autonomous weapons beyond meaningful human control" forthwith.[6]

These developments therefore pose a policy problem for national decision makers, including those in Denmark. Should Denmark join many of its NATO Allies and invest in weapon systems with autonomous functions so that the Danish armed forces can enjoy the advantages these systems possess and remain compatible with their partners? Should government officials pause at the moral, ethical, and legal implications of empowering machines that can choose to do as they will to perform military tasks on their behalf? Should they oppose or opt out of any strategy or policy that relies upon them? Or are developments insufficiently clear to justify making a decision in the near term? Any of these alternatives – join in, oppose, opt out, or wait – could be a reasonable policy response.

The purpose of this report[7] is to provide information and knowledge that could help answer such questions. Autonomous weapon systems may represent an historic advance in military technology and may have many implications for how states and non-state actors use military force. They will likely have an impact on warfare and war, defence policies, and certainly have implications for investments in research, development, and materiel acquisition. This report is intended to serve as a primer on the issues that incorporating autonomous functions into weapon systems pose to political officials, policy makers, military commanders, and their respective staffs. It is intended to bring them into the loop so that, together, they can consider these issues as they engage in discussions about defence policy.

This report is divided into five sections, including this introduction. In the next section we present how key government and international actors have defined weapon systems with autonomous functions, provide a conceptual map to differentiate between different degrees of autonomous functioning, and discuss the relationships between man and machine and their implications for directly controlling the machine in both time and across space. The third section catalogues the Danish inventory of weapon systems that possess some degree of autonomous functionality to impress the point that such weapon systems are already in the possession of the Danish armed forces. In the fourth section, we discuss the move from *direct* to *meaningful* human control as a basis for policies related to weapon systems with autonomous functions. The fifth section suggests convening an inter-ministerial working group to consider many of the policy issues raised by the technological developments leading to autonomous functionality in weapon systems, including:

- clarifying Denmark's definition of weapon systems with autonomous functions
- clarifying matters of principle and general Danish policy
- operationalising the concept of "meaningful human control" in terms of command and control arrangements
- recommending a permanent working group to consider the issues sure to arise in the implementation of the policy, including the acquisition, integration, and utilisation of weapon systems with autonomous functions

We conclude the report with a few thoughts about the role of violence and the control of its implements in human history.

2. Weapon Systems with Autonomous Functions

This section of the report reviews the definitions of autonomous weapons used by the British Ministry of Defence (MoD), the American Department of Defense (DoD), NATO Allied Command Transformation (ACT), the United Nations (UN), the International Committee of the Red Cross (ICRC), and the Danish MoD. After noting their areas of agreement and difference, we address three key dimensions that impact on the degree of "autonomy" extant in any weapon system: the degree of complexity with which it can behave without direct human control, the relation of the human operator to the machine, and when the instructions that guide its operations are imparted to the weapon. In doing so, we discuss the concepts that have been used to describe and define mechanical functions that occur without immediate human direction, including *autonomy*, *automated*, *automatic*, and *remotely controlled* systems. After defining them, we present a conceptual map to differentiate between these concepts. We then discuss the potential ways that direct control over such machines by a human being can be structured in terms of the man being in, on, or out of the loop of its operation once activated. We then address the dimension of when the instructions that guide its operations are imparted to the machine and how that timing interacts with its ability to perform its functions discriminately. We conclude the section with a discussion of how these dimensions can help structure an approach to weapon systems with autonomous functions.

2.1 Policy Definitions

The ability of weapon systems to be pre-programmed sufficiently to utilise high volumes of sensor inputs from multiple sources to effectively determine courses of action and other behaviours that fulfil the intent of its operator is ever-increasing. Indeed, one need only examine the transition from "dumb" bombs to "smart weapons" in NATO air operations or the increasing number and complexity of functions ably performed by remotely controlled systems to see the promise and allure that the integration of these technological trends holds for more effective and discriminating applications of lethal force. These sorts of weapon systems have recently become sufficiently common and their operations sufficiently complex to merit specific guidelines and policies to anticipate and control their development and use, particularly when they are capable of autonomously selecting and engaging targets with lethal force. In Text Box 1, we present the definitions of autonomous weapon systems upon which the British MoD, the American DoD, NATO Allied Command Transformation (ACT), the UN, the ICRC, and the Danish MoD have come to base their guidelines and policies.

Text Box 1: Official Conceptions of Autonomous Weapon Systems

In May 2011, the United Kingdom (UK) incorporated a definition of autonomous systems into its *Joint Doctrine Note 2/11: The UK Approach to Unmanned Aircraft Systems*. It states that:

- An autonomous system is capable of understanding higher level intent and direction. From this understanding and its perception of its environment, such a system is able to take appropriate action to bring about a desired state. It is capable of deciding a course of action, from a number of alternatives, without depending on human oversight and control, although these may still be present. Although the overall activity of an autonomous unmanned aircraft will be predictable, individual actions may not be.[8]

In November 2012, the United States (US) became the first government to issue a policy on autonomous weapon systems. Then-Deputy Secretary of Defense Ashton Carter issued DoD Directive 3000.09, which set policy and defined autonomous weapon systems in the following terms:

- autonomous weapon system: A weapon system that, once activated, can select and engage targets without further intervention by a human operator…
- human-supervised autonomous weapon system: An autonomous weapon system that is designed to provide human operators with the ability to intervene and terminate engagements, including in the event of a weapon system failure, before unacceptable levels of damage occur.
- semi-autonomous weapon system: A weapon system that, once activated, is intended to only engage individual targets or specific target groups that have been selected by a human operator.[9]

In April 2013, Christof Heyns, the Special Rapporteur on extrajudicial, summary, or arbitrary executions for the UN, defined *"lethal autonomous robots,"* or LARs, as:

- robotic weapon systems that, once activated, can select and engage targets without further intervention by a human operator. The important element is that the robot has an autonomous 'choice' regarding selection of a target and the use of lethal force.[10]

By May 2014, the term of art used by a "meeting of experts" for the 117 States party to the UN Convention on Certain Conventional Weapons (UN CCW) became "lethal autonomous weapon systems," or LAWS.[11]

In November 2013, Kathleen Lawand, the Head of the ICRC Arms Unit, defined:

- an 'autonomous weapon' [as] one that is programmed to learn or adapt its functioning in response to changing circumstances in the environment in which it is deployed. A truly autonomous weapon system would be capable of searching for, identifying and applying lethal force to a target, including a human target (enemy combatants), without any human intervention or control. This definition connotes a mobile system with some form of artificial intelligence, capable of operating in a dynamic environment with no human control.[12]

In October 2014, NATO Allied Command Transformation "suggested" a definition for "autonomous functioning":

- the ability of a system, platform, or software, to complete a task without human intervention, using behaviours resulting from the interaction of computer programming with the external environment…. This can be contrasted against automated functions, which although require no human intervention, operate using a fixed set of inputs, rules, and outputs, whose behaviour is deterministic and largely predictable. Automatic functions do not permit dynamic adaptation of inputs, rules, or outputs.[13]

The authors warned against "using autonomous + [system/platform/robot/machine/etc.]," since "it singles out 'autonomy' as a descriptor for the machine over and above all the other features and capabilities of the machine."[14]

Finally, in September 2016, the Danish MoD published a new military manual to provide its personnel with a "solid foundation for solving the tasks that they face in the world's hot spots," in the words of then-Defence Minister Peter Christensen.[15] The manual defines *autonomous weapon systems* as:

- By automatic (autonomous) systems we mean that each weapon is able to position and orient itself using electronic (often GPS-based) equipment. Autonomous systems can also calculate their own targeting data from the target coordinates that it has received digitally – possibly directly from an observer – and translate them into targeting data. Autonomous systems are usually self-propelled systems, but there are also towed systems with built-in navigation and positioning equipment, as well as digital fire control systems.[16]

These official definitions vary in their precise terms, but there is significant overlap. Most of them describe a machine capable of (1) *observing* the environment in which it exists, (2) *orienting* itself to this environment based on its sensor inputs, (3) evaluating potential courses of action and *deciding* on one, and (4) *acting* to implement that choice.[17] Most of these definitions also pay specific attention to machines that can select and engage targets with lethal force. These characteristics define the core of the problem. Yet there are issues that remain conceptually opaque in these definitions, particularly with regard to the complexity of behaviour required to deem a machine to be "autonomous," the relationship between human operators and the machine, and when the instructions and information guiding its operations are imparted to the weapon. We address each of these dimensions in turn.

2.2 Conceptual Clarifications

What is *autonomy*? Philosophers of a proceduralist bent argue that *autonomy* is the ability to render and act upon independent judgments regarding the appropriate course of action given the circumstances.[18] As such, autonomy is common to the human condition. What is new and different today is that machines are increasingly endowed with the capability to recognise and render independent judgment about courses of action.[19] The "fusion of sensor technology with advanced computational and processing power has enabled commercial and military platforms to become more aware of their environment and interact with it in the absence of human control."[20] The integration of increasingly powerful sensors and computing power will enable humans to progressively delegate more tasks to machines, including complex tasks that have no rote answer and require the exercise of judgment. As a 2012 NATO report puts it, "autonomous system[s have] the ability to understand higher-level intent and direction, and to choose from multiple alternatives. Although its overall function is by design, individual actions and final outcome may be unknown" to the person that delegates the task to the machine.[21] The potential for unpredicted behaviour in the pursuit of goals derived from "higher-level intent and direction" is the quality that makes autonomy potentially valuable – as well as risky and a cause of concern.

Although common language may conflate automatic, automated, and autonomous functionality – explicitly so in the Danish definition – using different terms to capture gradations in the sophistication of the actions that machines can take absent direct human control can help clarify the distinction between what has come before, what exists today, and what may come in the future. The terms autonomous, automatic, and automated autonomous are often used interchangeably because they denote functions that occur outside of direct human control.[22] Yet one can and should distinguish between the levels of complexity that the machine is capable of performing once it leaves direct human control because this is the quality that is changing. Distinct levels of complexity can be captured by considering three factors: (a) the number and types of inputs to the system, the number and types of outputs from the system, and the rules that link the two; (b) the relationship between the operator and the machine; and (c) when instructions and sensor inputs are provided to the machine and its outputs are determined.

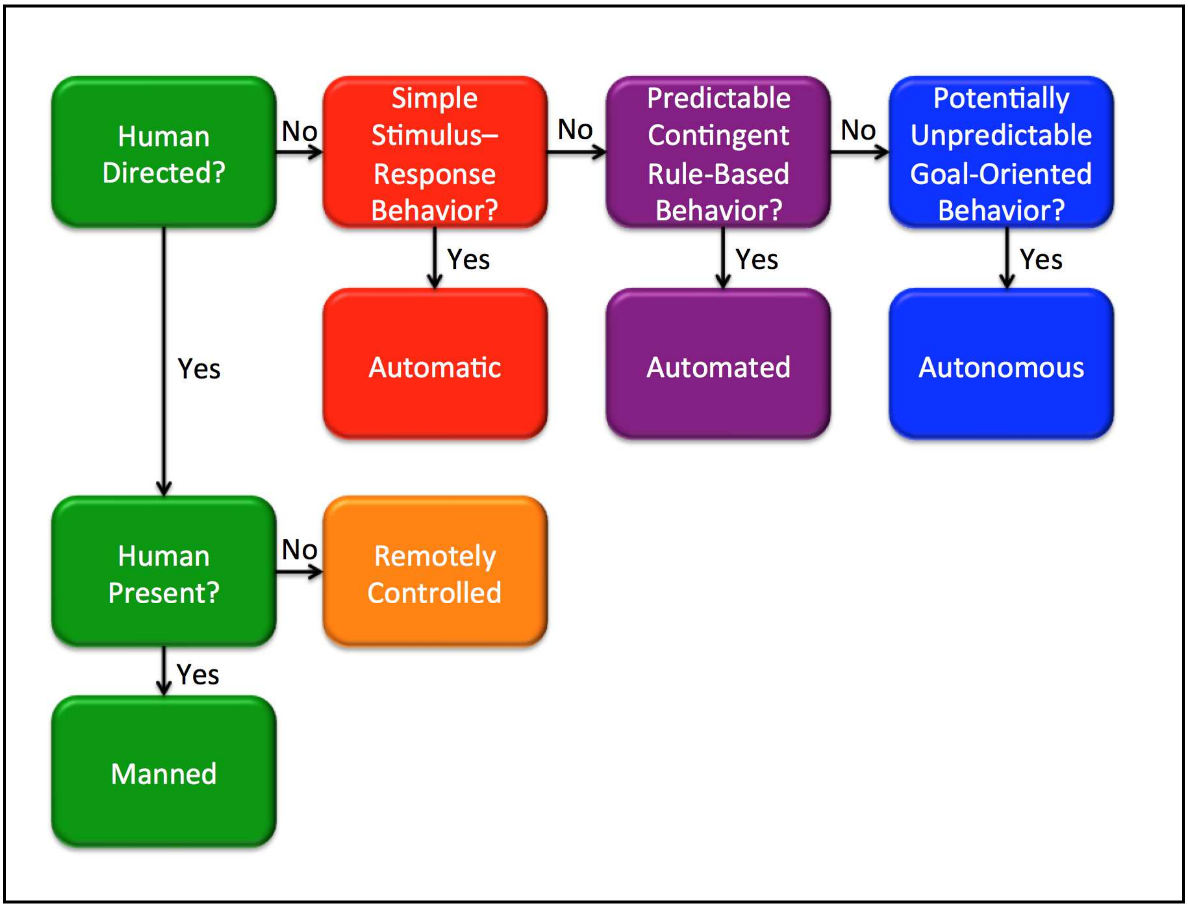
Automatic functions are of the stimulus-response type and imply "very simple, mechanical responses to environmental input," such as tripwires, landmines, and depth charges.[23] Such mechanisms function bluntly, utilizing a small number of sensory inputs (often one) and link them directly in a binary on/off fashion to a small number of outputs (often one). Automatic systems are not designed to respond effectively with any degree of nuance to the signals they could potentially receive from the environment. The inability of automatic weapons, such as anti-personnel landmines, to respond discriminately to environmental inputs is the reason that they have been subjected to significant scrutiny under international law.[24]

Automated functionality implies a greater degree of contingency built into the mechanism's response to environmental stimuli. These mechanisms use contingent, rule-based algorithms of the branch-and-sequel type to determine appropriate behaviour based on environmental inputs acquired after activation. They have "fixed choice points, programmed with a number of fixed alternative actions that are selected by the system in response to inputs from particular sensors" and whose "output is predictable if the set of rules under which it operates is known."[25] While automated functions can handle more complex sensory input than automatic functions, they lack the potentially "emergent behaviour that was not directly predictable from an inspection of its code" that characterises autonomous functionality.[26]

Finally, it is often suggested that "drones" or "unmanned aerial vehicles" (UAVs) are autonomous weapon systems.[27] This is not the case, at least for the systems that have been used to date, such as the *Predator*, *Reaper*, *Global Hawk*, or *Tårnfalken*.[28] Systems that function autonomously differ from these sorts of *remotely controlled* vehicles that remain under the direct control of a human, albeit one communicating with it at a distance. As the US DoD *Unmanned Systems Integrated Roadmap, FY 2013–2038* states, "when an aircraft is under remote control, it is not autonomous. And when it is autonomous, it is not under remote control."[29]

Figure 1 presents a conceptual map to help distinguish between these different terms and concepts for machines that can perform their functions without direct and proximate human direction.

Figure 1: Conceptual Map of Terms Associated with "Autonomy"



With this simple diagram, we can order these concepts in a manner that captures the degree of complexity that their operations imply along a continuum, ranging from a situation in which the human operator directly controls every action (i.e., manned or via remote control), through various levels of automated functions, the parameters of which have been predefined by a human operator and the machine's behaviour is deterministic and largely predictable – whether in terms of simple stimulus–response relations or predictable contingent behaviour of increasing complexity, to machines whose functions are guided by algorithms that enable adaptive and potentially unpredictable goal-oriented behaviour in complex situations or in response to unanticipated stimuli.[30]

Although this diagram draws a clear distinction between functions that are directed by a human being and those that are not, it does not detail the interactive man–machine relationship.

This relationship – the extent to which human operators control, direct, and/or cancel functions, and when – is determined in the design of the system, which incorporates considerations of the complexity of the tasks to be performed relative to system sensor, computing, and reactive capabilities as well as legal, ethical, and policy constraints. These man–machine relationships apply equally to systems with automated, automatic, and autonomous functionality – i.e., the relationship is *independent* of the degree of complexity with which the system interacts with its environment.

Much of the literature uses the pithy parlance of where the human operator stands in relation to the machine's decision making: *in-the-loop, on-the-loop, or out-of-the-loop*. Functions that have a man-*in*-the-loop are those that require a positive affirmation from the human operator for the machine to proceed. This is a simple delegation relationship. Man-*on*-the-loop functions are those where the operator need not approve of the action beforehand but retains the ability to veto it before the execution of the machine's action or abort the action once it has begun. These "human supervised" delegatory relationships can be more complicated. As the US Navy's Office of Naval Research defines it, in a man-on-the-loop man–machine relationship:

> The system can perform a wide variety of activities given top-level permission or direction by a human. The system provides sufficient insight into its internal operations and behaviours that it can be easily understood by its human supervisor and appropriately redirected [including being vetoed]. The system does not have the capability to self-initiate behaviours that are not within the scope of its current directed tasks.[31]

Edging toward man-*out-of*-the-loop functions are those that can be initiated by either the human operator or the machine, with various rules for their interaction.[32] These can include offering the human a complete or narrowed list of alternatives to choose from based upon the machine's assessment of the situation, suggesting a course of action to the human operator (known as cueing), and initiating action while permitting the human a limited amount of time to veto it.[33] Functions that have the man-out-of-the-loop entirely are those that the machine can initiate and execute without further interaction with a human operator and that cannot be vetoed or aborted. Such systems are said to be fully automatic, automated, or autonomous,[34] "requir[ing] no human intervention to perform any of its designed activities across all planned ranges of environmental conditions."[35] Man-out-of-the-loop relationships do not necessarily imply complete ignorance of the machine's behaviour, however. The relationship can be structured so as to require the machine to inform its human operator of its actions, or to do so only if asked, or only if the machine decides to do so.[36] Thus, there are many ways to structure the relationship between a human operator and a system with automatic, automated, or autonomous functions – and, as this implies, these relationships are not specifically dependent upon the complexity of the inputs, outputs, or decision rules programmed into the mechanism.

One final level of complexity deals with distinguishing between *when* and *to what degree* the human operator imparts instructions to the machine that is being unleashed. "Dumb" projectile weapons, such as arrows, bullets, artillery shells, and gravity bombs, put distance between their operator and their ultimate functioning but have no capacity to carry additional information about what behaviour is appropriate beyond that imparted to them mechanically at the time of launch. Hence, knowing the target's location, having good aim, and accounting for the potential effect of environmental factors such as wind are all part of the "programming" imparted to such projectiles. Weapons with automatic functions can receive simple information from their environment – temperature, barometric pressure, or altitude – after they have been activated and are "programmed" mechanically to respond to that information in a simple way. Landmines, time bombs, and booby traps are all examples of relatively simple automatic weapon systems where the man is out of the loop once the device is planted and armed. Increasing the ability of the mechanism to sense its environment and determine more fine-grained behaviour through automation further enables the human operator to determine the conditions under which the weapon will perform its functions prior to its activation. Thus weapon systems, such as "self-navigating mines" that resemble a torpedo but station themselves at a pre-determined location to wait for sensor information regarding their target,[37] enable additional control that is removed in both time and space from the operator's direct interaction with and control of the weapon system. The promise, if one accepts that normatively freighted term, of fully autonomous functioning is that the ability of the machine to sense its environment and be preprogramed sufficiently to determine appropriate courses of action based on that information prior to its launch is increasing tremendously. Indeed, at least in commercial civilian applications, such as automobiles, the objective is to pre-program sufficiently numerous and nuanced scenarios that can be recognised based on multiple sensor systems to enable an ever-attentive machine to react to its environment in ways more effective than human beings, thereby reducing the risks and dangers to people and property.[38] How well the distance in space and time is bridged by the technology inherent in the system and the institutional setting within which it is embedded (e.g., road systems, traffic laws, and the propensity of drivers and pedestrians to adhere to them) will prove to be a key consideration in the development of policies to address these emerging capabilities.

2.3 Conclusion

Advances in sensor and computing technology have incrementally enabled weapon systems to be operated at greater distances and behave in more discriminating ways as they accomplish their missions. Remotely controlled vehicles and “smart” weapons have increasingly removed weapons from direct human control in time and space while increasing their effectiveness – in particular their ability to react to environmental inputs after being activated and to use that information to perform their functions more discriminately. These advances have reached the point that governments and others have begun to consider weapons that behave beyond direct human control as a category requiring specific policy guidance. While the statements of these official bodies vary somewhat, they do focus on what is new: the increasing ability of weapons of war to sense and react to their environment in the absence of direct human control. Yet some distinctions that undergird current discussions about these weapon systems and can affect how they are treated by all stakeholders remain unclear. We have therefore provided a conceptual roadmap to help distinguish between systems that operate beyond direct human control with differing degrees of complexity, the relation between the human operator and the machine, and the point in time when the machine receives the information required to fulfil its functions. These distinctions can help policy makers more clearly distinguish what is new, what is not, and what requires additional attention.

3. Denmark's Weapons with Autonomous Functions

In this third section of the report we discuss some of the weapons in the arsenals of the United States, United Kingdom, and Denmark that are able to function with some degree of autonomy. We do so in the context of a survey of officers and officials in the Danish MoD, Defence Command, and the Danish Acquisitions and Logistics Organisation that was conducted for this report to better understand the capabilities of weapon systems in the Danish arsenal. Drawing on their responses, we discuss the autonomous functionality of some of the weapons used by the Danish armed forces.

As discussed in the previous section, weapon systems that can be operated remotely and those with automatic, automated, and autonomous functionality are becoming increasingly common in the armed forces of many countries, including the United States and most members of NATO. The US Navy, for instance, has for decades deployed many weapon systems with automatic, automated, and autonomous functions – including some that are able to select and engage targets with lethal force. During Operation Iraqi Freedom, for instance, the US Navy used an underwater autonomous system to detect submerged mines in the Persian Gulf.[39] Since the 1980s, US Navy vessels have been protected by a close-in defensive system that consists of "a radar-directed Gatling gun with an autonomous mode" known as the *Phalanx* to protect them from aircraft and other projectile weapons.[40] Finally, the *Aegis* ballistic missile defence system that forms the backbone of NATO Ballistic Missile Defence (BMD) can autonomously detect incoming ballistic missiles across an entire region and fire on them automatically.[41]

Such weapon systems are not confined to the United States or to navies. The United Kingdom fields the *Brimstone* anti-tank weapon on its combat aircraft, which the Royal Air Force describes as,

> a fully autonomous, fire-and-forget, anti-armour weapon, effective against all known and projected armoured threats.… During the search phase of the engagement, Brimstone's [radar] seeker searches for targets in its path, comparing them to a known target signature in its memory. The missile automatically rejects returns which do not match (such as cars, buses, buildings) and continues searching and comparing until it identifies a valid target. The missiles can be programmed not to search for targets until they reach a given point,

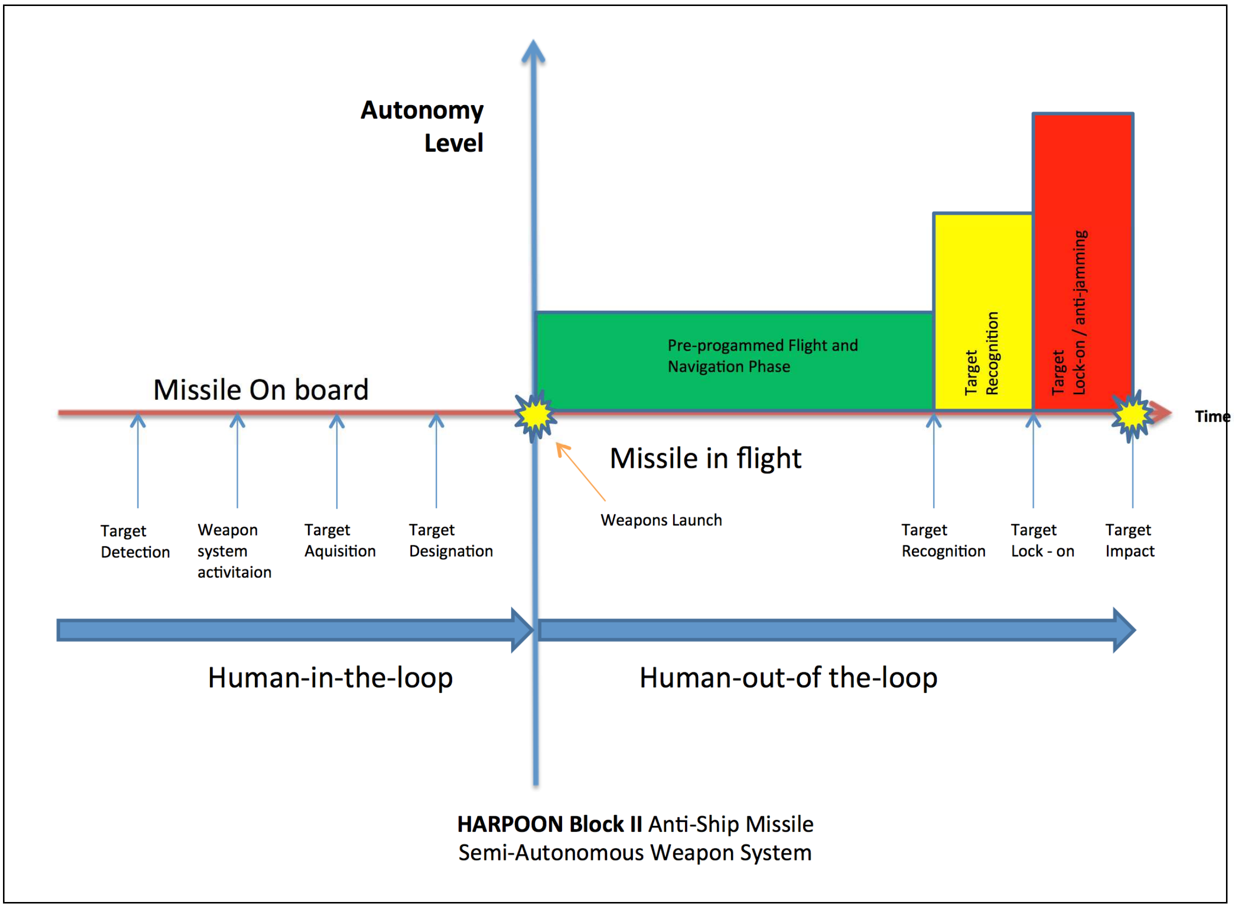
allowing them to safely overfly friendly forces, or only to accept targets in a designated box area, thus avoiding collateral damage.[42]

Denmark also possesses weapon systems with varying levels of automatic, automated, and autonomous functionality. As part of this study, we conducted a survey of Danish personnel in the Danish Acquisition and Logistics Organisation (DALO), Defence Command, and the MoD to determine whether Denmark possessed or planned to acquire weapon systems with autonomous functionality.[43] To assess the Danish inventory of weapons, the respondents were presented with definitions of autonomy and the man–machine relationship from the US DoD Directive 3000.09.[44] They were then asked to identify every weapon system of which they had knowledge that they deemed to have autonomous functions. For each weapon system, they were asked to identify its level of autonomy from specified options, to describe the functions and tasks of the weapon systems in an open-ended response area, and to specify the type of man–machine relationship from specified options.

The survey revealed that *Denmark already possesses* weapon systems with some functions that enable the weapon to behave beyond direct human control and would be characterised as "semi-autonomous" under DoD Directive 3000.09. The Royal Danish Navy possesses and deploys with the *Harpoon* Block II anti-ship missile, the *Evolved Sea Sparrow* surface-to-air missile, the *EuroTorp* MU90 Advanced Lightweight Torpedo, and the Terma Soft Kill Weapon Decoy Launching System that utilises different versions of *Sea Gnat* chaff ammunition.

The Danish Navy's *Harpoon* Block II missile is one example of a Danish weapon system with different levels of functionality beyond the direct control of its operator – particularly in the selection and engagement with targets with lethal force. In Figure 2 we map two key dimensions – phases of the weapon system's operation and the degree of autonomy delegated to the machine at different points in it – to better, but still imperfectly, capture the manner in which the *Harpoon* Block II missile can be considered autonomous.

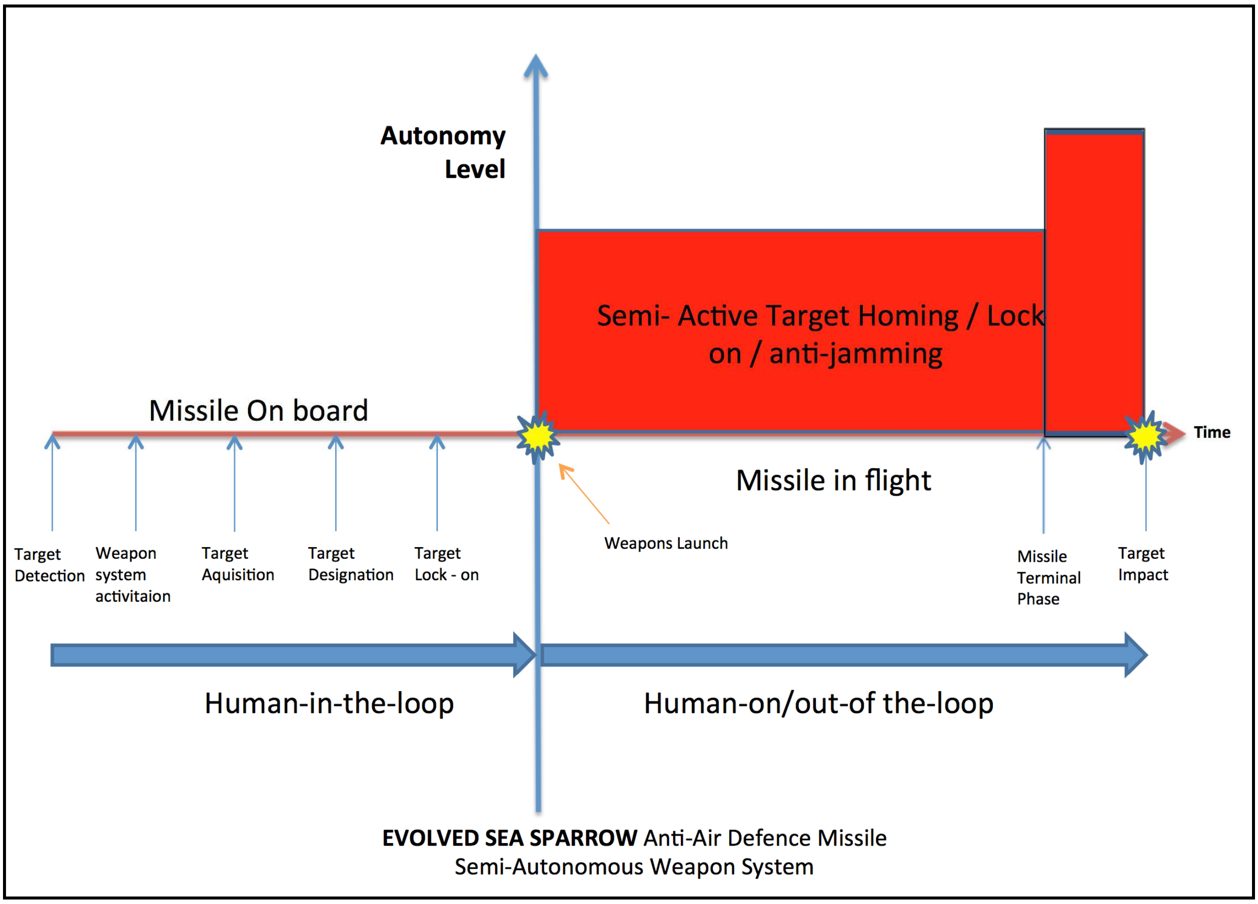
Figure 2: The Harpoon Block II Anti-Ship Missile System



As shown in Figure 2, during the target detection to target designation phases with the missile on board there is no autonomous functioning of the system. This changes after launch, however, when the system operates in an automated manner, following a pre-programmed flight and navigational algorithm. The missile's target recognition system is also automated, comparing data from radar- and or infra-red sensors and matching it against pre-programmed target identification criteria. The missile's flight functions, however, become fully autonomous as it performs directional corrections, including evasive manoeuvres and utilising electronic countermeasures systems in response to sensor inputs as it locks onto the target in its terminal phase.

A second system in the inventory of the Danish Navy is the *Evolved Sea Sparrow* air defence missile. It also functions with a degree of autonomy once activated, but the type and degree of autonomy across the phases of its operation differs from those of the *Harpoon* Block II system. Figure 3 maps the phases of the *Evolved Sea Sparrow's* operation and the degree of autonomy delegated to the machine at different points in its operation.

Figure 3: The Evolved Sea Sparrow Air Defence Missile System



As shown in Figure 3, the *Evolved Sea Sparrow* does not function absent human involvement while the missile is on board; that is, from the target detection phase to the weapons launch phase. After launch, the system operates with increasing degrees of autonomy as it actively searches for, homes in on, and locks onto its intended target. During this "track on target" mode, the missile corrects its flight path, engages in evasive manoeuvres, and can use electronic countermeasures to jam enemy detection systems in an automated manner as it locks onto the target in its terminal phase. Unlike the *Harpoon*, however, the human operator remains on the loop and the *Evolved Sea Sparrow's* flight can be terminated by its human operator at any point after launch, thus providing a failsafe form of control over its automated functioning.

The Royal Danish Air Force possesses comparable weapon systems, including the AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM), the AGM 65 *Maverick* air-to-ground missile, the AN/ALQ 162 Countermeasure system, and the AN/ALQ 213 Electronic Warfare Counter Measure System.[45] Danish military ships and aircraft also have defensive systems with autonomous functions. The Navy's *Sea Gnat* chaff munitions on its ships and the Air Force's F-16 countermeasures systems are fully autonomous *once engaged*. This is because these systems are designed to react swiftly to detect and react to threats that would exceed the reaction time of the crew. These systems are passive once activated and engage threatening munitions when they are detected, either by jamming them or launching a decoy to disrupt their ability to lock onto and destroy the Danish ship or plane. The Danish Army was found not to possess any weapon systems with automated or autonomous functions in its inventory.

As this review demonstrates, Denmark has weapons with different levels of autonomous functionality. So do its closest allies. Thus, concern with the types of functions that have been delegated to machines, the man–machine command relationship that determines when, where, why, and how the autonomous weapon system will be used, and the crucial moment of delegation wherein the machine determines its own behaviour outside of direct human control are issues that already exist for the Danish armed forces but, perhaps, have not been subjected to significant reflection. In the next section, we discuss one way of approaching the challenge of maintaining human control over weapons with autonomous functions.

4. From Direct to Meaningful Human Control

The fourth section of the report addresses the concept of meaningful human control. First, we establish that concerns have been raised about the increasing distance in time and space between human operators and weapon systems and that this distance has separated the concept of *direct* human control from that of *meaningful* human control. We then discuss two conceptions of meaningful human control that have been intended to provide a basis for ensuring that weapon systems with autonomous functions can be used in ways that are compatible with extant legal, ethical, and moral frameworks that guide the use of force.

Advances in sensor and computing technology have had two contradictory effects. On the one hand, they have increasingly removed weapons from *direct* human control in time and space. Fewer weapons require a human operator to be present to "close with the enemy" with accuracy and are "pre-programmed" so that they can perform their functions in the absence of an operator. On the other hand, despite this distance in time and space, weapon systems have become more precise and discriminating. Technology has not only enabled greater range but also increased accuracy.[46] This virtuous synergy has enabled "riskless" or "postmodern" war, where those who possess this technology can use military force against an adversary with less risk to their own forces or civilian bystanders.[47] Additional advances in these technologies promise to extend the control over weapon systems in both time and space, with greater pre-programming enabled by increased information-processing technology and better sensors enabling greater knowledge of local conditions providing a basis for more, and more nuanced and contingent, behaviour by machines further removed from direct human control.

Concerns have been raised about this trend. Indeed, many have argued that there is something morally or ethically wrong with the act of delegating greater decision authority, particularly decisions to use lethal force, to machines – regardless of their capability to sense and process information.[48] Yet delegation is nothing new to military institutions. Commanders delegate authority and responsibility to their personnel all of the time, enabling those personnel to select and engage targets with lethal force, even when those people were considered to be "the dregs of society."[49] Military institutions have developed elaborate mechanisms to control their personnel, to monitor their behaviour, and discipline deviations from expected and appropriate behaviour.[50] Each member is indoctrinated to respect the chain of command and every subordinate is monitored by a direct superior; and those superiors are responsible for the behaviour of their subordinates, up and down the chain of command.[51] Such interlocking mechanisms of command and control ensure appropriate behaviour as well as accountability and remediation of inappropriate behaviour.

Such practices play a particular role in the use of force by Western militaries, especially in a coalition setting where multiple sovereign governments share in oversight of the use of force. For instance, NATO forces utilise a six-phase decision cycle when force is used, which includes an analysis of the commander's operational goals; developing, validating, nominating, and prioritising targets; analysing the capabilities available to strike those targets; assigning the capabilities to be used against those targets; planning and executing the missions against those targets; and assessing the results. In each phase, the military commander and his subordinates undertake all of the necessary steps to satisfy the applicable operational and legal norms, including international law and established rules of engagement.[52] When things go awry, as they did when coalition forces – including Danish – bombed positions manned by Syrian military forces in a location believed to be occupied by ISIS forces,[53] the thoroughness of these processes enable investigations to determine what went wrong, who may be responsible, and who ought to be held accountable.[54] These practices provide significant incentives to use military force responsibly.

Ensuring that such procedures, norms, rules, laws, and institutions enable human decision makers to remain in control, act responsibly, and be held accountable for the use of violence in the face of technological advances that enable greater time and distance between decisions and the actions of weapon systems requires continuous diligence from military forces, governments, international institutions, and the international community. The laws of armed conflict have been designed on the premise that human beings exercise direct and meaningful control over violence and are therefore capable of adhering to the laws of armed conflict. Indeed, without direct and meaningful human control, the principles of military necessity, proportionality, distinction between civilians and noncombatants, minimisation of collateral damage, and the avoidance of unnecessary suffering become problematic.

But increasingly autonomous weapon systems open ever-more space between direct and meaningful human control in the force-related decision cycles. This leads to the question as to whether the two concepts are coterminous. "If the trend toward ever-greater autonomy continues, the concern is that humans will start to fade out of the decision-making loop, first retaining only a limited oversight role, and then no role at all."[55] More specifically, as Heather Roff and Richard Moyes write, "questions relating to what is required for human control to be 'meaningful' are open, as well as how far away in distance and/or time a human has to be from an act in question for there to be 'human control'."[56]

This is important because if *direct* human control over weapon systems with autonomous functions may fade, then *meaningful* human control is necessary if they are to meet any standards of legitimacy.[57] The Danish government has officially contributed to this debate and may be considered part of this consensus. In April 2015, Susanne Rumohr Hækkerup, the Danish Ambassador for Disarmament, submitted a statement for the record to the UN CCW Informal Meeting of Experts on Lethal Autonomous Weapon Systems that "all use of force – including the use of autonomous weapon systems – must be in compliance with international humanitarian law, i.e., the fundamental rules of distinction, proportionality and precautions in attack. And all use of force must remain under 'meaningful human control'."[58]

But what is "meaningful human control"? In a document distributed to the participants of the second Meeting of Experts on Lethal Autonomous Weapon Systems (LAWS) at which Ambassador Hækkerup spoke, Michael Horowitz and Paul Scharre argued that there are general conditions that can be specified to ensure meaningful human control over weapon systems, including those that exercise substantial autonomy. They argued that "meaningful human control" has three essential components:

- Human operators are making informed, conscious decisions about the use of weapons.
- Human operators have sufficient information to ensure the lawfulness of the action they are taking, given what they know about the target, the weapon, and the context for action.
- The weapon is designed and tested, and human operators are properly trained to ensure effective control over the use of the weapon.[59]

By locating the concept of meaningful human control into the institutional setting within which a weapon is used, this position provides a way to incorporate autonomous weapon systems into existing legal, ethical, and moral institutions, exemplified above in NATO targeting procedures, intended to restrain, channel, and minimise conflict and its costs. It does so by providing conditions that apply to all weapon systems – as Ambassador Hækkerup stated. Indeed, this position enables one to argue that any weapon system with any degree of automatic, automated, or autonomous functionality will always be under meaningful human control as long as they are wielded by Western militaries, as such militaries always design and test their weapons, always train their personnel in the proper use of their weapons, are embedded in a targeting process that ensures that they have sufficient information to evaluate the lawfulness of their actions, and that they are making informed and conscious decisions about the use of such weapons. These conditions would hold true for a slingshot as well as for a fully autonomous lethal robot.

And yet it seems to us that this solution does *not* address what is potentially new about autonomous weapon systems; that is, that machines will be able to observe their environments, orient themselves toward an objective, consider and decide upon a course of action, and then act upon its own judgment in ways that are potentially unknown and cannot be predicted by its human operator – with potentially deadly consequences for human life. The Horowitz and Scharre criteria ingeniously sidestep the issue of when and to what degree the human operator has control over a weapon system, whether direct or otherwise. Rather, they treat the weapon system as if it has no autonomy at all and allocate full responsibility for its use to its human operator or their chain of command. Thus their proposal rightly invited continued discussion to determine the contours and content of the concept.

In that spirit, Heather Roff and Richard Moyes have suggested a more direct standard of "meaningful human control" to supplement this sort of institutional conception. They argue that "the key elements for human control are:

- Predictable, reliable and transparent technology.
- Accurate information for the user on the outcome sought, operation and function of technology, and the context of use.
- Timely human action and a potential for timely intervention.
- Accountability to a certain standard.[60]

Of particular importance in light of the increasing distance between *direct* human control and *meaningful* human control, transparency in the decision rules that a system uses to translate sensory inputs into actions ought to be clear for the users of the system. As Roff and Moyes argue:

> The technology ought to be designed so that if necessary, one can interrogate the system to inform the user or operator about the decisions, goals, subgoals or reasoning that the system used in performing its actions. [Furthermore, t]here should be clear goals, sub-

> goals and constraints emplaced on each system, and it must be possible for human operators to understand these.[61]

Only if the technology is designed in such a way to permit a typical user to understand its operation can they make informed, conscious, and meaningful decisions about the use of the weapon system.

Given the potential variation in the nature of the man–machine relationship (potentially with man entirely out of the loop), the degree of autonomy delegated to the machine (potentially full autonomy to act to achieve an objective), the points at which this delegation can occur throughout the decision cycle for each of its functions – i.e., when the distance between direct and meaningful human control will expand in its use – and the ability of the system to sense, assess, communicate with its operator, recommend or choose a course of action, and act in time to be effective, it seems to us that much more work must be done to apply a conception of “meaningful human control” in any policy context. Indeed, it is to that policy context that we now turn.

5. Organising for the Autonomous Future

Denmark currently has no overarching policy toward weapon systems with autonomous functions that is comparable to those of the United States or the United Kingdom. Few statements of policy have been made publicly. Those that have, such as the definition of autonomous systems contained in the new military manual and Ambassador Hækkerup's focus on the meaningful human control of such systems, are not necessarily synchronous. Nor have structures, processes, or procedures for ensuring the exercise of meaningful human control been elaborated within the Danish armed forces. Although the lack of a policy is merely a situation until it is defined as a problem to be resolved, it may be prudent to consider it before an unforeseen event makes the situation acute.

Danish authorities have recently faced similar situations with regard to cyber warfare and the domestic uses of remote-controlled aerial vehicles. Technological advances and systems integration that had been developing over the past decade reached a point at which officials determined that a problem existed and that a policy or strategy was necessary to address it. In each case, they convened an inter-ministerial working group (*tværministeriel arbejdsgruppe*) to consider the implications of those developments for government policy.[62] In the case of the cyber strategy, the inter-ministerial working group consisted of representatives from the Ministry of Foreign Affairs, the Ministry of Justice, the Ministry of Defence, Defence Intelligence Service, and the Joint Services Defence Command.[63] As the case of autonomous systems traverses diplomatic relations, Danish defence policy, domestic and international legal issues, as well as military planning, procurement, and operations, we suggest that a similar working group be formed to address the situation, with representatives from these ministries and perhaps others that have relevant competencies and stakes in the outcome.

There are four primary issues that this working group could consider in the construction of recommendations for a general policy. First, it could clarify the government's definition of what constitutes a weapon system with autonomous functions, perhaps using the conceptual discussion provided in the second section of this report. Second, it could evaluate arguments regarding whether Danish policy should (a) support and shape – or oppose – the development, deployment, and use of such weapon systems by its armed forces, the Danish defence industry,[64] and/or its Alliance partners, (b) permit – or oppose – the stationing or passage of such weapons in or through Danish territory, and (c) participate in – or abstain from – military operations in which this class of weapons would be used. In this instance, the question is one of whether weapon systems with autonomous functionality are “conventional” weapons, albeit ones with advanced capabilities, or “unconventional weapons” along the lines of nuclear, chemical, or biological weapons – the characteristics of which require additional moral, ethical, and practical consideration. Third, provided that it is decided that Danish policy will permit the development, acquisition, deployment, and use of such weapon systems, the working group should grapple with operationalising the concept of “meaningful human control” to establish an institutional structure of command and control that can ensure that authority, responsibility, and accountability for the use of these weapon systems are both synchronous and effective.

Finally, the inter-ministerial working group could suggest a permanent working group be established within Defence Command to consider practical issues in the implementation and adjustment of policies pertaining to weapon systems with autonomous functions. This permanent group could consider the contribution that these types of weapon systems could make to accomplishing core Danish military tasks. The permanent working group should possess the competencies to conduct legal reviews of such weapons at the earliest possible stage in the study, development, and acquisition cycle to determine their compatibility with the relevant laws of armed conflict as required by Article 36 of Additional Protocol 1 of 1977 to the four Geneva Conventions. Furthermore, this group should ensure that clear parameters exist to establish the legal guidance for the use of the weapon systems, including restrictions, if any. Such reviews could consider whether a system can be used in a lawful manner in all circumstances or only in certain restricted circumstances. If the latter is the case, these circumstances should be included in associated concepts of operations and rules of engagement and then propagated through the proposed command structure.

Furthermore, this permanent working group could:

- Consider what participation in NATO Ballistic Missile Defence means in terms of delegating decision authority to weapon systems with autonomous functions and the extent to which decision making can be legitimately delegated to NATO command structures outside of Danish control.
- Enhance Danish participation in all NATO Multinational Capability Development Campaign (MCDC) working groups that deal with weapon systems with autonomous functions to expand the Danish knowledge base.

- Sponsor technical tests and experiments with autonomous systems in the Arctic and other parts of the Kingdom and involve potential partners in these to create the basis for discussing future joint requirements.
- Actively support efforts by national and international aviation and maritime authorities to establish solid regulations for the use of aviation systems with autonomous flight control functions in civilian airspace and territorial waters.

6. Concluding Remarks

Human beings have engaged in organised conflict with one another for millennia. Man's ingenuity in developing tools that can be used for violence demanded the development of norms, rules, laws, and institutions to restrain and channel their ever-increasing range, speed, and destructive capacity. The increasing lethality of the battlefield has also driven developments to remove combatants from harm's way. The increasingly frequent and effective use of unmanned aerial vehicles by Western states over the past 25 years has likely been only a precursor to further developments.[65] Technological and strategic trends indicate that weapon systems with autonomous functions will be developed, be more capable, be widely available, and ever more usable as weapons of warfare. They potentially possess characteristics that will render them extremely useful to military forces – and seductive to political leaders. Weapon systems with autonomous functions will enable greater persistence, range, mass, daring, speed, and coordination among military forces – while at the same time reducing the risks to military personnel by removing them from the weapons that populate the battlefield.

This development threatens to make warfare literally inhuman. It raises key issues that should be addressed by responsible armed forces, governments, and other stakeholders. This includes very important issues such as defining autonomy and autonomous weapon systems, determining the conditions that must be met for them to be used responsibly, and the manner and regimes under which their users are to be held accountable. Danish decision-makers may find it advantageous to contemplate the implications of this development.

7. Notes

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[1] Weapon systems with autonomous functions are one dimension of "The Third Offset Strategy" that will guide American, NATO, and allied defence policy, strategy, and acquisitions in the years ahead. See Robert O. Work, "'National Defense University Convocation' as Delivered by Deputy Secretary of Defense Bob Work, National Defense University, Washington, D.C.," *Department of Defense Press Operations* (5 August 2014); Robert O. Work, "'A New Global Posture for a New Era,' as Delivered by Deputy Secretary of Defense Bob Work, Council on Foreign Relations, Washington, D.C.," *Department of Defense Press Operations* (30 September 2014); Robert O. Work, "'The Third U.S. Offset Strategy and Its Implications for Partners and Allies' as Delivered by Deputy Secretary of Defense Bob Work, Willard Hotel, Washington, D.C.," *Department of Defense Press Operations* (28 January 2015); Robert O. Work, "'Army War College Strategy Conference' as Delivered by Deputy Secretary of Defense Bob Work, U.S. Army War College, Carlisle, PA," *Department of Defense Press Operations* (8 April 2015); Robert O. Work, "'Naval Postgraduate School Commencement' as Delivered by Deputy Secretary of Defense Bob Work, Naval Postgraduate School, Monterey, CA," *Department of Defense Press Operations* (19 June 2015).

[2] David Ignatius, "In Munich, a Frightening Preview of the Rise of Killer Robots," *The Washington Post* (17 February 2016); David Ignatius, "The Exotic New Weapons the Pentagon Wants to Deter Russia and China," *The Washington Post* (23 February 2016).

[3] Campaign to Stop Killer Robots, "The Problem," available at http://www.stopkillerrobots.org/the-problem/, accessed 23 August 2015.

[4] Nolan Feeney, "Elon Musk and Stephen Hawking Join Call for Ban on Artificially Intelligent Weapons," *Time* (27 July 2015), available at http://time.com/3973500/elon-musk-stephen-hawking-ai-weapons/, accessed 22 January 2016.

[5] "Autonomous Weapons: an Open Letter," *Future of Life Institute* (28 July 2015), available at http://futureoflife.org/open-letter-autonomous-weapons/, accessed 22 January 2016.

[6] "Autonomous Weapons: an Open Letter."

[7] The authors followed the procedures described in the CMS project manual in the preparation of the report. The CMS project manual stipulates a set of quality control procedures for projects that are part of the research-based government services offered by the Centre. This report has been carried out by the Centre for Military Studies in accordance with the contract between the University of Copenhagen on behalf of the parties to the Danish Defence Agreement 2013–17. More information about the Centre, the procedures for quality control, and the contract can be found at the Centre's homepage at http://www.cms.polsci.ku.dk. The authors assessed the relevant literature as part of a desk study and communicated with dozens of Danish military officers and defence officials, officials in NATO Allied Command Transformation, officials in the US Office of the Secretary of Defense, and American civilian experts. The authors also conducted a survey of officers and officials in the Danish MoD, Defence Command, and the Danish Acquisitions and Logistics Organization in order to better understand the capabilities of weapon systems in the Danish arsenal. We thank them for their time and assistance.

[8] Assistant Head, Air and Space (Development, Concepts and Doctrine), *Joint Doctrine Note 2/11: The UK Approach to Unmanned Aircraft Systems* (Shrivenham: The Development, Concepts and Doctrine Centre, Ministry of Defence, 30 March 2011), page 2–3.

[9] Ashton B. Carter, *United States DoD Directive 3000.09: Autonomy in Weapon Systems* (Washington: DoD, 21 November 2012), pages 13–14.

[10] Christof Heyns, *Report of the Special Rapporteur on Extrajudicial, Summary or Arbitrary Executions. A/HRC/23/47* (New York: UN General Assembly, 9 April 2013), pages 7–8.

[11] At the 2013 CCW Meeting of High Contracting Parties, a new mandate on lethal autonomous weapons systems (LAWS) was agreed on," ("2014 Meeting of Experts on LAWS," UN Office at Geneva (undated), available at http://www.unog.ch/__80256ee600585943.nsf/(httpPages)/a038dea1da906f9dc1257dd90042e261?OpenDocument&ExpandSection=1%2C2#_Section1, accessed 8 February 2016. Neither NATO nor the US DoD has adopted this terminology, however.

[12] Lawand, "Fully Autonomous Weapon Systems."

[13] Arthur Kuptel and Andrew Williams, *Policy Guidance: Autonomy in Defence Systems. Multinational Capability Development Campaign (MCDC) 2013–2014 Focus Area: "Role of Autonomous Systems in Gaining Operational Acces*s (Norfolk: Allied Command Transformation, 29 October 2014), page 11; *emphasis* added.

[14] Kuptel and Williams, *Policy Guidance*, page 11.

[15] Forsvarsministeriet, "Militærmanual i høring," *Press Release* (20 January 2016), available at http://www.fmn.dk/nyheder/Pages/militaermanual-i-hoering.aspx, accessed 24 January 2016. Author's translation.

[16] Jens Rynkeby Knudsen, Chef for Projektgruppen*, Militærmanual Om Folkeret For Danske Væbnede Styrker i Internationale Militære Operationer* (Copenhagen: MoD, September 2016), page 578. Author's translation.

[17] This is known as the "OODA Loop." See William C. Marra and Sonia K. McNeil, "Understanding 'The Loop': Regulating the Next Generation of War Machines," *Harvard Journal of Law & Public Policy* 36, 3 (Summer 2013), page 1145.

[18] Jane Dryden, "Autonomy," in *The Internet Encyclopedia of Philosophy*, available at http://www.iep.utm.edu/, accessed 6 May 2016; Gerald Dworkin, *The Theory and Practice of Autonomy* (Cambridge: Cambridge University Press, 1988); Gerald Dworkin, "The Concept of Autonomy," in John Christman, editor, *The Inner Citadel: Essays on Individual Autonomy* (Oxford: Oxford University Press, 1989); Harry Frankfurt, *The Importance of What We Care About* (Cambridge: Cambridge University Press, 1988).

[19] Prominent robotic engineers such as Noel Sharkey dismiss the idea of robots being able to understand higher level intent and directions all together (Noel Sharkey, "Automating Warfare: Lessons Learned from the Drones," *Journal of International Law, Information, and Science* 21, 2 (2011).

[20] Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age* (Washington: Center for a New American Security, January 2014), page 24.

[21] *Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles. STO-TR-HFM-184* (Cedex: NATO Science and Technology, December 2012), page F-1, available at https://www.cso.nato.int/pubs/rdp.asp?RDP=RTO-TR-HFM-184, accessed 22 January 2016. This discussion draws on the definition of autonomous systems promulgated in the *UK Approach to Unmanned Aircraft Systems, Joint Doctrine Note* 2/11 (JDN 2/11) (Shrivenham: Development, Concepts and Doctrine Centre, MoD, 30 March 2011), pages 2–3.

[22] Systems referred to in this report as systems with automated functions are similar or identical to systems with so-called structured control (see, e.g., Armin Krishnan, *Killer Robots: Legality and Ethicality of Autonomous Weapons*, (Farnham: Ashgate, 2009).

[23] Paul Scharre, *Robotics on the Battlefield. Part 1: Range, Persistence and Daring* (Washington: Center for a New American Security, May 2014), page 13.

[24] See the *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-personnel Mines and on Their Destruction*, which entered into force on 1 March 1999 and is available at http://www.icbl.org/media/604037/treatyenglish.pdf.

[25] Andrew Williams, "Defining Autonomy in Systems: Challenges and Solutions," in Andrew P. Williams and Paul D. Scharre, editors, *Autonomous Systems: Issues for Defence Policymakers* (Norfolk: Capability Engineering and Innovation Division, Headquarters Supreme Allied Commander Transformation, 2014), page 32.

[26] Scharre, *Robotics on the Battlefield. Part 1*, page 13.

[27] Arthur Holland Michel, "Drones in Popular Culture," (Annandale-On-Hudson: Center for the Study of the Drone at Bard College, 4 September 2015), available at http://dronecenter.bard.edu/drones-popular-culture/, accessed 19 November 2016.

[28] Jason Koebler, "Air Force General: Autonomous Killing Drones 'Years and Years' Away," *U.S. News and World Report* (24 April 2013), available at http://www.usnews.com/news/articles/2013/04/24/air-force-general-autonomous-killing-drones-years-and-years-away, accessed 19 November 2016; Gary Schaub, Jr., Kristian Søby Kristensen, and Flemming Pradhan-Blach, *Long Time Coming: Developing and Integrating UAVs into the American, British, French, and Danish Armed Forces* (Copenhagen: Centre for Military Studies, April 2014).

[29] James A. Winnefield and Frank Kendell, *Unmanned Systems Integrated Roadmap, FY 2013–2038* (Washington: DoD, 2013), page 15.

[30] This conception is similar to that produced by the NATO Industrial Advisory Group (NIAG). See James E. Harris, chairman, *Pre-Feasibility Study on UAV Autonomous Operations* (Brussels: NIAG Special Group 75, 2004).

[31] US Navy's Office of Naval Research, quoted by Williams, "Defining Autonomy in Systems," in Williams and Scharre, *Autonomous Systems*, page 42.

[32] US Navy's Office of Naval Research, quoted by Williams, "Defining Autonomy in Systems," in Williams and Scharre, *Autonomous Systems*, page 42.

[33] These relations draw upon Sheridan's scale of automation as presented by Williams, "Defining Autonomy in Systems," in Williams and Scharre, *Autonomous Systems*, page 41. See Thomas B. Sheridan, *Telerobotics: Automation and Human Supervisory Control* (Cambridge: MIT Press, 1992).

[34] Depending on the degree of contingency and predictability in the machine's functionality.

[35] US Navy's Office of Naval Research, quoted by Williams, "Defining Autonomy in Systems," in Williams and Scharre, *Autonomous Systems*, page 42.

[36] These relations draw upon Sheridan's scale of automation as presented by Williams, "Defining Autonomy in Systems," in Williams and Scharre, *Autonomous Systems*, page 41.

[37] Sydney J. Freedberg Jr., "Sowing The Sea with Fire: The Threat of Sea Mines," *Breaking Defense* (30 March 2015).

[38] Cadie Thompson, "Why Driverless Cars Will Be Safer than Human Drivers," *Business Insider UK* (17 November 2016), available at http://uk.businessinsider.com/why-driverless-cars-will-be-safer-than-human-drivers-2016-11?r=US&IR=T, accessed 19 November 2016.

[39] Patrick Tucker, "Will Subdrones Cause World War III?" *Defense One* (7 September 2015).

[40] Tucker, "Will Subdrones Cause World War III?"

[41] Tucker, "Will Subdrones Cause World War III?"

[42] Royal Air Force, "Brimstone: Fully Autonomous, Fire-and-Forget, Anti-Armour Missile," in *Royal Air Force: Aircraft and Weapons* (London: MoD, 2007), page 87, available at http://www.raf.mod.uk/rafcms/mediafiles/0186cc2a_1143_ec82_2ef2bffff37857da.pdf, accessed 1 May 2016). *Brimstone*, as described, would be categorized as a semi-autonomous weapon system under DoD Directive 3000.09.

[43] The survey was conducted from 2 October through 2 November 2015. A purposive sample of 19 experts within the MoD was identified using their position within the organization or their technical expertise. They were contacted by e-mail and invited to participate in our survey. Twelve of the 19 experts responded (63% response rate). The survey queried their position, background, service, and duties. Twenty-nine percent of the respondents worked in Defence Materiel Command, 43 percent worked in Defence Command, and 29 percent worked in another agency. Ten of the respondents (86%) were military officers, one was a civilian official, and one was a military officer serving in a civilian capacity. Three respondents were from the Danish Army, four from the Danish Navy, and three from the Danish Air Force. Finally, 11 of the 12 respondents (93%) answered affirmatively when asked if their work duties included advising or recommending the types of weapon systems that the Danish military should acquire or purchase.

[44] Autonomous weapon system

- A weapon system that, once activated, can select and engage targets without further intervention by a human operator. This includes human-supervised autonomous weapon systems that are designed to allow human operators to override operation of the weapon system, but can select and engage targets without further human input after activation.

Semi-autonomous weapon system

- A weapon system that, once activated, is intended to only engage individual targets or specific target groups that have been selected by a human operator. This includes:
    - Semi-autonomous weapon systems that employ autonomy for engagement-related functions including, but not limited to, acquiring, tracking, and identifying potential targets; cueing potential targets to human operators; prioritizing selected targets; timing of when to fire; or providing terminal guidance to home in on selected targets, provided that human control is retained over the decision to select individual targets and specific target groups for engagement.
    - "Fire and forget" or lock-on-after-launch homing munitions that rely on tactics, techniques, and procedures to maximize the probability that the only targets within the seeker's acquisition basket when the seeker activates are those individual targets or specific target groups that have been selected by a human operator.

Human-supervised autonomous weapon system

- An autonomous weapon system that is designed to provide human operators with the ability to intervene and terminate engagements, including in the event of a weapon system failure, before unacceptable levels of damage occur.

Man–Machine Relationship

- Man not in the loop
- Man in certain phases of weapon system operation
- Man involved throughout with a dead man's switch

[45] Some responses indicated that Danish officers believed the GBU 31 Joint Direct Attack Munition (JDAM) to be semi-autonomous, but it is not. Prior to bomb release, the guidance unit of the GBU 31 will be fed with aircraft position, velocity, and target co-ordinates through the aircraft-to-bomb interface. After release, the bomb guides itself to the target by means of control surfaces on the rear fins, which are driven by commands from an onboard computer that is constantly being updated by the GPS. If no GPS signals are received, the JDAM kit will guide the weapon using the Inertial Navigation System (INS) alone.

[46] Work and Brimley, *20YY*, pages 10–16.

[47] Chris Hables Gray, *Postmodern War: The New Politics of Conflict* (London: Routledge, 1997); George R. Lucas Jr., "Postmodern War," *Journal of Military Ethics* 9, 4 (2010); Bradley Jay Strawser, "Moral Predators: The Duty to Employ Uninhabited Aerial Vehicles," *Journal of Military Ethics* 9, 4 (2010); Anders Henriksen and Jens Ringsmose, "Drone Warfare and Morality in Riskless War," *Global Affairs* 1, 3 (2015).

[48] Noel Sharkey, “Saying ‘No!’ to Lethal Autonomous Targeting,” *Journal of Military Ethics* 9, 4 (2010); Peter W. Singer, “The Ethics of Killer Applications: Why Is It So Hard To Talk About Morality When It Comes to New Military Technology?” *Journal of Military Ethics* 9, 4 (2010); Heather M. Roff, “The Strategic Robot Problem: Lethal Autonomous Weapons in War,” *Journal of Military Ethics* 13, 3 (2014).

[49] Paul Y. Hammond, “The Political Order and the Burden of External Relations,” *World Politics* 19, 3 (April 1967), page 444.

[50] Gary Schaub Jr. and Ryan Kelty, “From Making to Buying: Controlling the Coercive Capacities of the Corporate Warrior,” in Gary Schaub Jr. and Ryan Kelty, *Private Military and Security Contractors: Controlling the Corporate Warrior* (Lanham: Rowman & Littlefield, 2016).

[51] Guénaėl Mettraux, *The Law of Command Responsibility* (New York: Oxford University Press, 2009).

[52] Mark Roorda, “NATO’s Targeting Process: Ensuring Human Control Over (and Lawful Use of) ‘Autonomous’ Weapons,” in Andrew P. Williams and Paul D. Scharre, editors, *Autonomous Systems: Issues for Defence Policymakers* (Norfolk: Capability Engineering and Innovation Division, Allied Command Transformation, 2014), pages 154–161; André Haider and Maria Beatrice Catarassi, *Future Unmanned Systems technologies: Legal and Ethical Implications of Increasing Automation* (Kalkar, Germany: NATO Joint Air Power competence Centre, November 2016).

[53] Anne Barnard and Mark Mazzetti, “U.S. Admits Airstrike in Syria, Meant to Hit ISIS, Killed Syrian Troops,” *The New York Times* (27 September 2016); Ritzau, “Danske F-16-fly Deltog i Fejlangreb mod Syrisk Militær,” *Berlingske* (18 September 2016); Ole Damkjær, “Danske Bombemål i Syrien er Nøje Afstemt med USA,” *Berlingske* (19 September 2016); Cathrine Bloch, “Forsvarsminister efter Muligt Fejlangreb i Syrien: ‘Vi Ved Ikke, Hvad der er Sket’,” *Berlingske* (19 September 2016).

[54] Ritzau, “FAKTA: Sådan får Danske Fly Udpeget Mål,” *Berlingske* (19 September 2016); Stephen Losey, ”Investigation: ‘Confirmation Bias,’ Mistakes Led Coalition to Mistakenly Bomb Syrian Troops,” *Air Force Times* (29 November 2016).

[55] The Campaign to Stop Killer Robots, “Focus on Meaningful Human Control of Weapons Systems: Third United Nations Meeting on Killer Robots Opens in Geneva,” (Geneva: The Campaign to Stop Killer Robots, 11 April 2016).

[56] Heather M. Roff and Richard Moyes, “Meaningful Human Control, Artificial Intelligence and Autonomous Weapons,” *Briefing paper prepared for the Informal Meeting of Experts on Lethal Autonomous Weapons Systems, UN Convention on Certain Conventional Weapons* (London: Article 36, April 2016), page 2.

[57] Mary Ellen O’Connell, “Banning Autonomous Killing: The Legal and Ethical Requirement that Humans Make Near-Time Lethal Decisions,” in Matthew Evangelista and Henry Shue, editors, *The American Way of Bombing: Changing Ethical and Legal Norms, From Flying Fortresses to Drones* (Ithaca: Cornell University Press, 2014); Caton, *Autonomous Weapon Systems*, pages 41–5; Mark Roorda, *NATO’s Targeting Process: Ensuring Human Control Over and Lawful Use of ‘Autonomous’ Weapons. Amsterdam Center for International Law Research Paper 2015–06* (Amsterdam: University of Amsterdam, 2015). Kuptel and Williams argue that “rather than

emphasizing the fact that a system employs autonomous functions, focus should be placed on the level of human control[,] accountability[,] and the type of decision being autonomised," (Kuptel and Williams, *Policy Guidance*, page 10).

[58] Susanne Ruhmour Hækkerup, "General Statement by Susanne Ruhmour Hækkerup, Ambassador for Disarmament, Non-Proliferation and Arms Control, 13 – 17 April 2015, Geneva," (Geneva: UN Office in Geneva (UNOG), 2015), available at http://www.unog.ch/80256EDD006B8954/(httpAssets)/C5B8B0A4AD379822C1257E26005D7D20/$file/2015_LAWS_MX_Denmark.pdf, accessed 21 January 2016.

[59] Michael C. Horowitz and Paul Scharre, *Meaningful Human Control in Weapon Systems: A Primer* (Washington: Center for a New American Security, March 2015), page 4.

[60] Roff and Moyes, "Meaningful Human Control, Artificial Intelligence and Autonomous Weapons," page 3.

[61] Roff and Moyes, "Meaningful Human Control, Artificial Intelligence and Autonomous Weapons," page 2.

[62] The Foreign Policy Committee and the Defence Committee, *Redegørlse fra den Tværministerielle Arbejdsgruppe om Folketingets Inddragelse ved Anvendelse af den Militære Computer Network Attack (CMA)-Kapacitet* (Copenhagen: Folketing, 2015); *Fremtidens Regulering af Civile Droner: Rapport fra en Tværministerielle Arbejdsgruppe* (Copenhagen: Trafikstyrelsen, March 2015).

[63] *Redegørlse fra den Tværministerielle Arbejdsgruppe om Folketingets Inddragelse ved Anvendelse af den Militære Computer Network Attack (CMA)-Kapacitet*, page 2.

[64] For instance, the unmanned aerial vehicles that may be developed and produced in Denmark by Sky-Watch in partnership with Boeing in the future for the US military (and others) will likely incorporate autonomous functions (Astrid Ildor and Niels Vedersø Østergaard, "Kampflygigant vil Sende Dansk Droneindustri på Himmelflugt," *Berlingske* (25 January 2016)).

[65] Schaub, Kristensen, and Pradhan-Blach, *Long Time Coming*.

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