The Hague Centre
for Strategic Studies

Robotic and Autonomous Systems: From design to development and use in military operations

Michel Rademaker and RNLA LtCol Sjoerd Mevissen

Robotic and Autonomous Systems:
From design to development and use in military operations

Authors: Michel Rademaker and RNLA LtCol Sjoerd Mevissen
Editor: Alessandra Barrow

Cover Image: Ministry of Defence. THeMIS firing, the UGV is armed with a .50 machine gun. Action photo taken during the live fire exercise in Bergen-Hohne, 2022.

All images in this report are courtesy of the Netherlands Ministry of Defence.

The Hague Centre for Strategic Studies
info@hcss.nl
hcss.nl
Lange Voorhout 1
2514EA The Hague
The Netherlands

Table of Contents

1. Introduction

Robots and Autonomous Systems (RAS) are an evolving industry for the military. Although the military's interest in RAS has been existed for decades, the use and application of such systems in experiments and in on the ground operations is relatively new and growing. This is also the case within the Dutch Armed Forces. In 2018 the Royal Netherlands Army established an experimental unit to explore RAS, the so-called fourth evolution of warfare. Alongside this unit, the army began field experiments and ongoing research covering a wide range of essential topics on the military use of RAS. This article[1] is a summary of this research, conducted over a two-year period. The military applications, the meaning of autonomy, ethical and legal considerations, and the need for a different approach within the army to keep up with technical innovations are briefly discussed in this paper. Subsequently, the paper describes the way the Dutch Armed Forces arranged their Concept Development & Experimentation (CD&E) plan and the friction it encountered, given the need for fast innovation and the reality of bureaucracy within a large organization. Finally, the paper reflects on the first findings and conclusions of the field experiments.

Figure 1. Operator and THeMIS. The operator uses the Remote Controlled Weapon Station which is (digitally) integrated on the platform. Pictured in Lithuania in 2022. Ministry of Defence.

[1] The research described in this paper was not intended for an academic audience though the methods used are in line with them. The reports conducted by *The Hague* Centre for Strategic Studies (HCSS) are available via https://hcss.nl/robotic-and-autonomous-systems-ras/.

2. What are RAS in a military context?

Robotic and Autonomous Systems (RAS) present numerous, significant and far-reaching opportunities within a military context. In order to observe the ways in which these systems are applicable in this context and evaluate their utility, some definitions and concepts need to be addressed:

Autonomy: The level of independence that humans grant a system to execute a given task. It is the condition or quality of being self-governing, to achieve an assigned task based on the system's situational awareness (integrated sensing, perceiving, analyzing), planning, and decision making. Autonomy refers to a spectrum of automation in which independent decision making can be tailored for a specific mission, level of risk, and degree of human-machine teaming. Levels of autonomy can range from remotely controlled (non-autonomous) Operator Assistance, Partial Automation, Conditional Automation, High Automation, or Full Automation.

Robot: A powered machine capable of executing a set of actions by direct human control, computer control, or both. It is composed minimally of a platform, software, and a power source.

Robotic and Autonomous Systems (RAS): RAS is an accepted term in academia, the science and technology (S&T) community that highlights the physical (robotic) and cognitive (autonomous) aspects of these systems. RAS is a framework used to describe systems with both a robotic element and an autonomous element. It is important to note that each of the consecutive parts of RAS covers a broad spectrum. The 'systems'-part refers to a wide variety of physical systems over a wide range of (military) application areas. Automated software systems running on computers or networks, including 'bots', pieces of software that can execute commands with no human intervention, do not qualify as RAS because they lack a physical component. The 'robotic' part, which refers to the physical layout of the system, holds that the system is unmanned or uninhabited. All other physical aspects (size, form, whether it flies, floats or rolls, etc.) are left open.

Lethal Autonomous Weapon System (LAWS): A weapon that, without human intervention, selects and engages targets matching certain predefined criteria, following a human decision to deploy the weapon on the understanding that an attack, once launched, cannot be stopped by human intervention.

Life Cycle: The life cycle concept encompasses the various phases of the system from design to manufacturing, testing, the use in operations and decommissioning. The responsibilities differ per phase as well as the aspects of the automated system. All in all, the overall responsibility for a well governed, within the legal and ethical boundaries defined, lifecycle of the automated (military and or dual use) components lies with the defence organization that orders the systems. In doing so its procurement specifications should entail these elements. Accountability for the functioning of its parts is to be taken up by the various producers of (sub)systems.

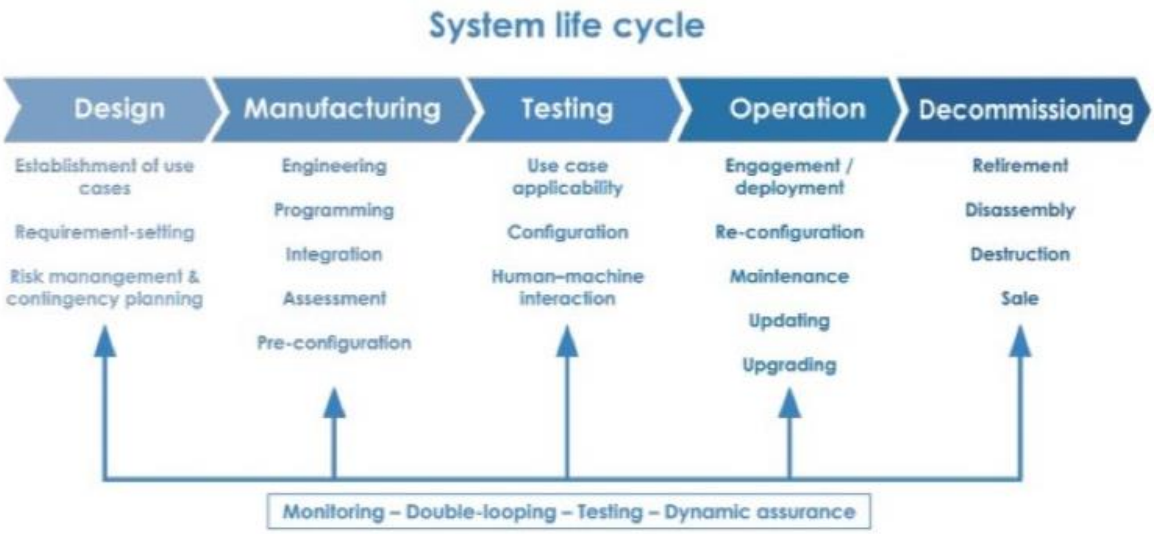

Figure 2. A system life cycle.

Meaningful human control (MHC): MHC encompasses (at least) the following three elements: (1) People make informed, conscious decisions concerning the use of weapons; (2) People are adequately informed in order to ensure that the use of force conforms to international law, within the scope of the knowledge that they have on the goal, the weapon, and the context in which the weapon is put to use; (3) The weapon in question has been designed and tested in a realistic operational setting and the people involved have received adequate training, in order to use the weapon in a responsible manner. MHC is a complex concept, and, in many cases, the above description is not conclusive. The official Dutch standpoint is that “all weapons, including autonomous weapons, must remain under meaningful human control.”

3. Concepts and application areas

The rhetoric of “killer robots” has narrowed the public’s view of robotic and autonomous systems in a military context to being exclusively about lethal use of force by highly or fully autonomous systems. In reality, RAS can be applied to numerous military functions and tasks, with various levels of autonomy in each function (See Figure 1). The broad military applicability of robotic and autonomous systems yields numerous and vast opportunities. The challenge for the years ahead is to make the most of these opportunities and wield the potential for military advantage whilst simultaneously mitigating the risks posed.

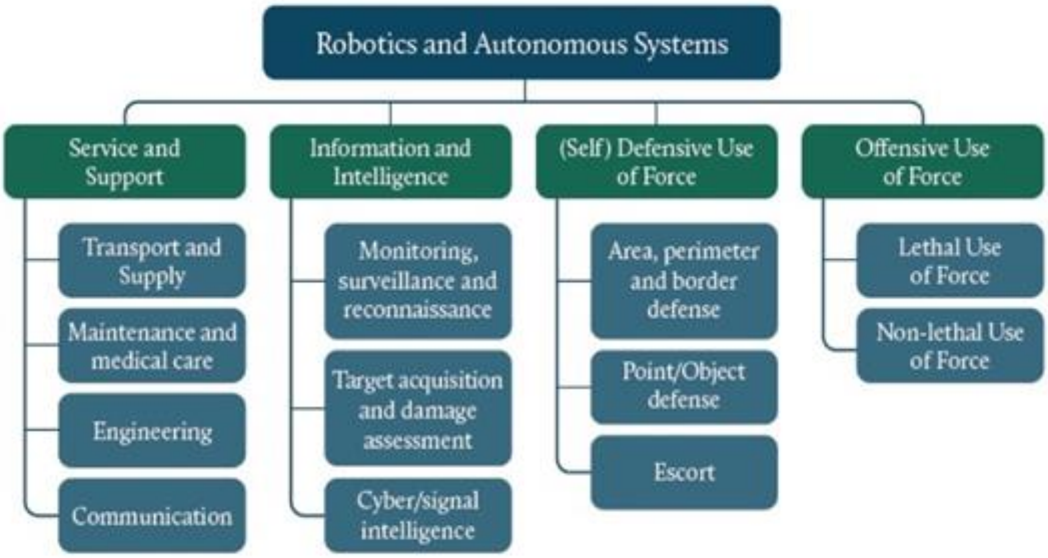

Figure 3. The range of application areas for RAS in a military context (Source: HCSS).

4. Assessing the military value of RAS

In order to gauge the added value of RAS to the military, it is necessary to identify the different ways in which these systems can (or cannot) positively contribute to the capabilities of military organizations. This safeguards against innovation for innovation's sake and frames the development of RAS in terms of its potential to produce tangible, perceivable outcomes. To determine the military utility of RAS we propose the following criteria (see Figure 2):

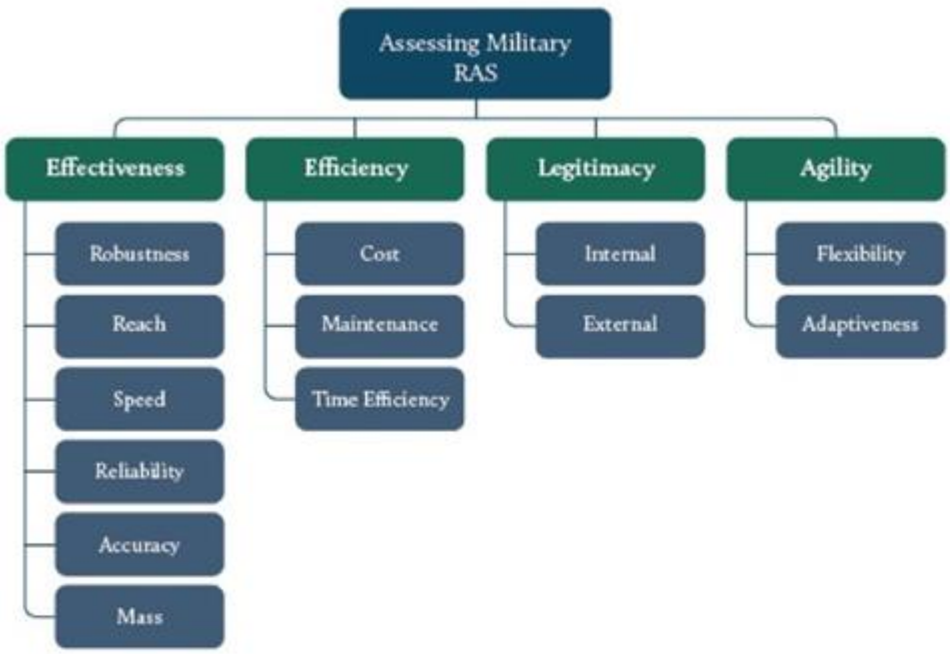

Figure 4. Evaluation Metrics used to Assess RAS (Source: HCSS).

1. **Effectiveness** to achieve the desired effect(s) or objective(s) for the military task(s)/ mission(s) where RAS is deployed.

2. **Efficiency** in the use of resources. Ideally, both the life cycle costs of the system (initial investment, maintenance, upgrades, etc.) as well as running costs (e.g., for fuel, spare parts, and repair) are taken into account.

3. **Agility** to adapt according to the requirements of the situation at hand, and also to adapt over time to new situations.

4. **Legitimacy** of the application of RAS, both in a formal sense and as perceived by the (military) operators and by the people/societies, in theatre as well as at home.

5. Overview of current systems

The dataset of RAS used by HCSS largely builds upon a SIPRI dataset which encompasses over 380 RAS classified into a number of general categories.[2] Our overview currently comprises 299 distinct RAS solutions. The majority of RAS are categorized under **Information and Intelligence**, while **Use of Force** has the least RAS solutions. It might be that the actual amount of RAS for **Use of Force** is broader than what can be asserted, precisely because of limitations due to the classification of matters concerning national security. Furthermore, collecting data on RAS in countries such as China and Russia is restricted by their known secrecy as well as language barriers.

A factual overview of current RAS is depicted using the HCSS taxonomy of military functions (see Figure 1). The section will proceed by firstly demonstrating the first tier of this taxonomy; and then by the second tier, which offers a more detailed account of potential military applications of RAS. In furtherance of providing a clear broad view of RAS production and use, visualizations will display the approximate number of projects produced/ employed per country.

We categorized 299 RAS based on their military functions, namely in the domains of **Service & Support**, **Information & Intelligence**, **Defensive Use of Force,** and **Offensive Use of Force**, forming

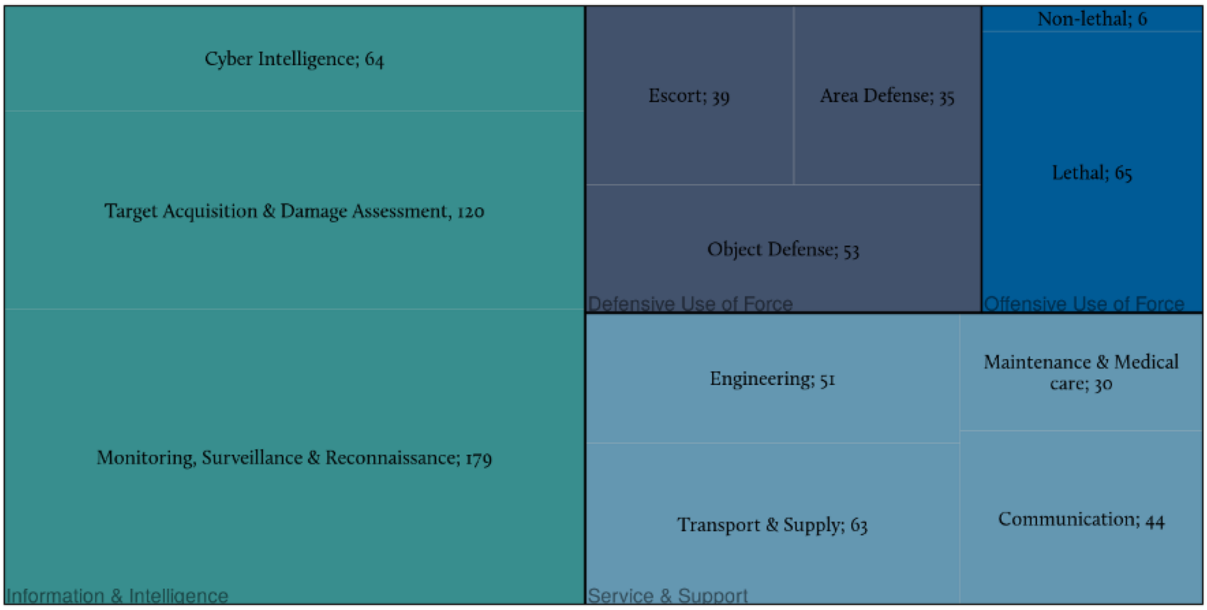

Figure 5. This represents Tier 2 of The HCSS RAS Taxonomy (Source: HCSS).

2 Despite the comprehensiveness of the SIPRI list, it contains several limitations, in particular with regards to its generic classification of RAS based on their purpose, i.e., their function. The SIPRI dataset ranges from systems that are operational, under development, and canceled/retired. For our purposes, the systems which are either retired or canceled were excluded, along with the systems employed in the maritime domain. Our overview also made use of systems identified in the British Army Innovation Technology Book (BAITB), as well as studies conducted by the U.S. Congressional Research Service, Zhifeng Lim, and Boulanin & Verbruggen. The resulting dataset used by HCSS is for 90% based on the SIPRI dataset, for 4-5% on the British Army Technology book, and for 5-6% on the additional studies. The data presented in this paper is accurate as of the time of writing: March 2019. “Army Warfighting Experiment 2018: Autonomous Warrior”; Feickert et al., U.S. Ground Forces Robotics and Autonomous Systems (RAS) and Artificial Intelligence (AI); Lim, “The Rise of Robots and the Implications for Military Organizations”; Boulanin and Verbruggem, “Mapping the Development of Autonomy in Weapon Systems.”

the first level of categorization. Figure 3, portrays the second tier of RAS, offering a more comprehensive view of HCSS' taxonomy of the systems.

Implementing RAS into these functions brings significant challenges, but also heralds new opportunities for militaries to be more effective, efficient, and agile. The potential of RAS to continue to (r)evolutionize the defense arena can be evaluated according to these categories.

Speed. With the help of artificial intelligence, which stimulates rapid decision making and prioritization of threats, RAS are already capable of surpassing human reaction times and shortening the OODA (Observe, Orient, Decide, Act) loop.

Reliability. Delegating tasks to machines requires an immense degree of trust and as of yet RAS cannot prove adequate reliability across all military application areas. However, our confidence in these systems will increase as they prove their reliability and effectiveness in executing specific tasks.

Accuracy. AI systems have developed facial image recognition and sensory abilities past the level of human performance, though the claim that unmanned systems are more precise than human operatives is widely disputed.

Mass. Owing to increased range and endurance, RAS has the capability to enhance coverage of the battlespace and overwhelm adversaries. The best example of this potential is 'swarming'.

Reach. RAS greatly enhance the available points of presence for surveillance, intelligence, reconnaissance, and weapons systems.

Robustness. In the short term, RAS will be more vulnerable than humans to fail due to unanticipated conditions including poor weather and changes to the mission. This frailty extends to the virtual domain: as losses in connection, hacking and other interference can render a system incapable.

Safety. RAS can perform 'dull, dangerous and dirty' tasks so that humans can focus on the more specialized tasks and be kept out of the line of fire.

Cost. Although exclusive access to the most cutting-edge technology will be reserved for the wealthiest players, the cost of systems that are now considered highly advanced will fall throughout the next twenty years, thus becoming more widely attainable.

Maintenance. Updating and upgrading RAS software and hardware may prove more difficult given the complexity of the systems and the multiple (external) partners involved.

Time efficiency. RAS can perform dull and repetitive monitoring tasks at a high standard 24/7 without the need for rest, logistical planning can be solved efficiently, and the limits of human multitasking can be quickly surpassed.

Flexibility. Although RAS currently excel in executing specific tasks and humans will remain the most flexible for the foreseeable future. This dynamic is likely to change as developers continue to innovate current systems.

Adaptiveness. RAS are highly adaptive and be easily reconfigured during the system's life cycle (scaled, extended, upgraded etc.) over time so to keep up with new requirements emerging in a dynamic environment.

External legitimacy. The military's engagement with RAS must thus strike a balance between the advanced capabilities they (potentially) provide and the values and norms of the society it serves.

Internal legitimacy. Trust and organizational normalization of RAS will be strengthened over time. As understanding of the systems, their predictability, and their familiarity grow, their legitimacy within the organization will solidify.

Figure 6. THeMIS During filming of the documentary Robotization in the Dutch Army, taken by HCSS.

6. Levels of autonomy

The 'autonomous' part of RAS is the most discussed and most constrained. A crucial notion is meaningful human control (MHC). The formal Dutch standpoint is that "all weapons, including autonomous weapons, must remain under meaningful human control." Again, there is no internationally accepted definition. MHC encompasses (at least) the following three elements:[3]

- People make informed, conscious decisions concerning the use of weapons.

[3] The dynamic core task of a RAS is the task performed in direct connection to the mission the RAS was set to do. For military applications, these various tasks can be derived from the categorization above. For a cargo drone, for instance, this core task would be navigating safely to a drop-off location, delivering the cargo intact, and returning home. For a surveillance drone, this would be to spot and track moving targets that fit certain characteristics.
[2] It is assumed that a core task can be broken down into functional aspects in a modular fashion. E.g., for the cargo drone, the core task would consist of a navigation part (to reach the drop-off location; as well as return home) and a drop-off part (deliver the cargo).

- People are adequately informed in order to ensure that the use of force conforms to international law, within the scope of the knowledge that they have on the goal, the weapon, and the context in which the weapon is put to use.
- The weapon in question has been designed and tested in a realistic operational setting and the people involved have received adequate training, in order to use the weapon in a responsible manner.

Yet, MHC is a complex concept, and, in many cases, the above description is not conclusive. Likewise, the often-used distinction between human-in-the-loop, human-on-the-loop, and human-out-of-the-loop does not suffice. These terms refer to the relationship between an unspecified human and an unspecified decision loop, whereas in reality a number of different humans may relate to various loops. Human-on-the loop refers to the situation in which a human has a monitoring function capable of intervening when required. Many of these loops are non-operational, e.g., play out in the design phase of RAS. Also, these terms cover the aspect of human control (or machine freedom). Two other concepts also embedded in the term autonomy are the complexity of the machine and the type of decision being automated.

For our purposes, we propose a taxonomy (see Figure 4) based on the SAE international standard J3016, which identifies six levels of driving automation to categorize self-driving cars.[4] We have slightly adapted that standard to fit our context of military use.

Levels of autonomy \ Categories of use	Service & Support	Information & Intelligence	Defensive Use of Force	Offensive Use of Force
0: Remotely Controlled				
1: Operator Assistance				
2: Partial Automation				
3: Conditional Automation				
4: High Automation				
5: Full Automation				

Figure 7. Levels of automation and subsets of automated systems[5]. (Source: HCSS).

[4] SAE International, "Automated Driving: Levels of Driving Automation Are Defined in New SAE International Standard J3016."
[5] HCSS compilation.

0: Remotely Controlled: the full-time performance by the operator of all aspects of the dynamic core task,[6] even when enhanced by warning or intervention systems.

1: Operator Assistance: the mode-specific execution by an assistance system of certain functional aspects[7] of the core task, using information about the environment, while the operator performs all remaining aspects of the core task, and with the expectation that the operator will respond appropriately to a request to intervene.

2: Partial Automation: the mode-specific execution by an assistance system of all functional aspects of the core task, using information about the environment, and with the expectation that the operator will respond appropriately to a request to intervene.

3: Conditional Automation: the mode-specific execution by one or more assistance systems of all functional aspects of the core task, using information about the environment, and with the expectation that the operator will respond appropriately to a request to intervene or/and can override the autonomous behavior.

4: High Automation: the mode-specific execution by one or more assistance systems of all functional aspects of the core task, using information about the environment, even if the operator does not respond appropriately to a request to intervene.

5: Full Automation: the full-time performance by an automated system of all aspects of the core task under all environmental conditions to at least the same level as can be managed by an operator.

7. What are the dilemmas?

7.1. *Societal considerations for the military applicability of RAS*

Ethical and legal considerations on the development, integration, and use of RAS for a military context abound. While the current ethical debate on robotic and autonomous systems (RAS) is often dominated by relatively extreme narratives surrounding a total ban on 'killer robots', current discussions on RAS have sidelined nuances that have critical implications for deciding how to introduce RAS in a military context. The brewing AI arms race and the diffusion of cheap, technologically advanced systems among state and non-state actors compels countries to adopt RAS. How militaries can do so whilst also keeping in-tact human agency, human dignity and responsibility is of great importance.

7.2. *Ethical considerations*

Maintaining human agency, particularly in the context of autonomous weapon system (AWS), is one of the most contentious issues of debate with respect to the integration of RAS in the military domain. Human agency is a concept that encompasses "self-control, morality, memory, emotion recognition,

[6] Horowitz and Scharre, "Meaningful Human Control in Weapon Systems," 4 This definition (in Dutch translation) is also used in the AIV/CAVV report, Autonome wapensystemen. De noodzaak van betekenisvolle menselijke controle, from October 2015.
[7] SAE International, "Automated Driving: Levels of Driving Automation Are Defined in New SAE International Standard J3016."

planning, communication and thought."[8] It includes "features of self-awareness, self-consciousness and self-authorship," and as a result relates to moral agency and affects the attribution of responsibility.[9]

Human control also referred to as 'meaningful human control' (MHC), is an operational component of human agency, which distinguishes between human and artificial decision making processes.[10] A fundamental aspect of maintaining MHC is the operator's understanding of the algorithmic process' parameters, the outcomes presented as a result of the computation, and the ability to explain the machine's path to the conclusion after the fact. From this point of departure stems an important ethical concern of RAS and AI in particular: the lack of algorithmic transparency. Algorithms such as neural networks suffer from opacity as they operate as 'black boxes', whereby the path taken by the algorithm to arrive at the conclusion is often not traceable.[11] The diminished understanding an operator has of such systems reduces their ability to predict and/or explain the system's reasoning process, undermining the control that the operator has over the outcomes and hence, the responsibility for its (mis)use. Furthermore, the evolutionary nature of algorithm-driven systems, both as a result of self-learning properties and software updates, has the potential to considerably affect the explainability of systems' actions. Self-learning AI that independently develops its understanding of the surrounding environment, automation bias, and excessive trust in system outputs may limit human control over a RAS system's operation. As the design of a system can incorporate various degrees of autonomy (from remote controlled to fully autonomous) within the multiple functions of a system across the Observe, Orient, Decide, Act (OODA) loop, meaningful human control principles should be considered at the earliest stages of development.

The fundamental guiding principle is to work with 'ethics by design', whereby ethical considerations are incorporated in the use case identification, system design, validation, manufacturing, and testing processes, rather than solely in the 'use' stage of the system life cycle. This entails building an understanding of the system performance and behavior early in the design and testing stages, by involving end users early, meaning that operators, supervisors, and commanders will be better able to trace, understand and predict the system's decision-making process. Best practice guidelines should be created for the outsourcing of the development process to external contractors.

7.3. *Legal considerations*

The lack of meaningful human control in RAS has given momentum to considerations for legal discourse and debate on governing autonomous weapons. International positions still differ widely, ranging from proponents and opponents of a ban on such weapons to a group of countries that lie in between and emphasize the need for further clarification and elaboration of existing regimes. It is clear however that current rules, standards, and practices are relevant but, most probably, insufficient to cover developments with regard to autonomous weapons. At the very least, RAS would require refinements of existing regulation. While the consensus based CCW/GGE[12] still counts as a necessary tool to further this debate, it is doubtful whether this effort alone is sufficient. Despite the inclusion of NGOs and academia, state parties are dominant in this format and industry is only present in a backbench capacity. Amid various approaches to definitions, norms, and standards at the international level, the Netherlands needs to decide on the directions of the modernization of its Armed Forces and its international posture amid an intensifying public debate.

---

[8] Gray, Gray, and Wegner, "Dimensions of Mind Perception."
[9] European Group on Ethics in Science and New Technologies (EGE), Statement on Artificial Intelligence, Robotics and "autonomous" Systems.
[10] MHC interrelates with "effective control", a prerequisite in public international law for legal liability and unlawful conduct. In the context of the use of RAS/AWS, the term is used alongside "effective command" to determine state responsibility.
[11] Preece, "Asking 'Why' in AI: Explainability of Intelligent Systems – Perspectives and Challenges"; Matthias, "The Responsibility Gap: Ascribing Responsibility for the Actions of Learning Automata," 178–79.
[12] The Group of Governmental Experts (GGE) of the High Contracting Parties to the Convention on Certain Conventional Weapons.

Legal approaches to regulate RAS include hard law, soft law, and voluntary measures. Hard law concerns binding treaties that are negotiated and agreed upon between states. Soft law involves quasi-legal instruments such as politically binding Codes of Conduct (CoCs) or Confidence and Security Building Measures (CSBMs), sometimes involving multiple stakeholders other than states. Finally, voluntary instruments include behavioral principles or norms and exchanges of best practices, or other information within or outside traditional arms control communities (see Figure 6).

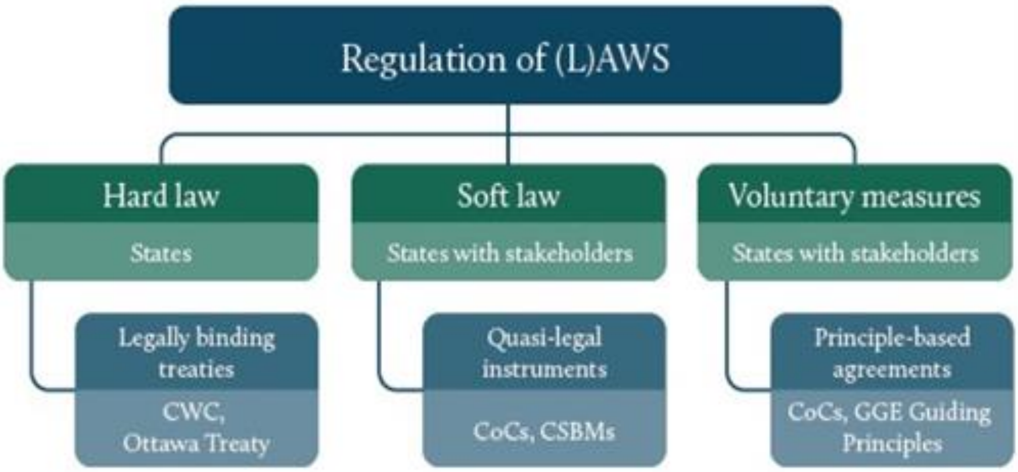

Figure 6: The three mechanisms for regulating (L)AWS.[13] (Source: HCSS).

[13] Authors' compilation. Codes of Conduct (CoCs) are categorized under both 'Soft law' and 'Voluntary measures' as different CoCs bind parties in different ways. For example, the OSCE Code of Conduct on Politico-Military Aspects of Security is 'politically binding' for all participating States of the OSCE, whereas the Hague Code of Conduct against Ballistic Missile Proliferation is a voluntary non-binding instrument open to all states. These two principle-based agreements thus highlight the thin line between soft law and voluntary measures.

8. Why is Concept Development & Experimentation Indispensable?

8.1. *Operational considerations for the military applicability of RAS*

Operational considerations for the military applicability of RAS involve the challenges posed by existing processes and the culture within the Armed Forces, specifically in regard to cooperation with external partners and concept development and experimentation (CD&E). In terms of cooperation, the emergence of RAS challenges the effectiveness of multi-stakeholder cooperation in a military context, especially when it concerns collaborative structures with the private sector. In addition to changes with external relations, the Armed Forces must also grapple with internal restructuring of CD&E processes, which will call into question not only the structural processes that guide the function of the organization but also broader doctrinal thinking. RAS are unique in that they ultimately can take humans 'out of the loop' and as a consequence, drastically affect operational performance, organizational embedding (e.g., influencing numbers, skills and training of personnel), and operational concepts (doctrine and tactics).

8.2. *Considerations for Cooperation*

As RAS development is to a great extent driven by civilian innovation, the integration of RAS creates demands for interaction with designers, developers, and manufacturers outside the traditional defence industry. Managing this relationship requires a) integrated and interdisciplinary cooperation, b) a clear division of tasks, investments, and responsibilities, c) the implementation of common system architecture and d) a balancing of military requirements and expectations, technological possibilities, and (potentially conflicting) legal, ethical and safety parameters.

Additionally, due to a rapid cycle of innovation within, for example, artificial intelligence (AI), RAS must be developed and acquired in fast-paced procedures, used for shorter periods of time, and modified, updated, inserted, or exchanged throughout the life cycle of the system. Whereas the integration of a regular system includes some sort of 'hand-over' from the developer/producer to the military organization who will use the new system. A feature of RAS is the dependency upon integrated software that continues to evolve; certainly, where self-learning algorithms are part of the autonomous reasoning of the system. As a result, the hand-over of RAS does not necessarily finalise the involvement of the producer in the latter stages of the life cycle. The producer must ensure that the system is adequately and regularly updated, and that the self-learning nature of the system is controlled and continues to meet demands and standards.

In contrast to these rapid cycles of innovation, societal discussions regarding ethical questions and legal uncertainties unfold slowly. These conversations demand interaction with a range of stakeholders and policy makers outside of defence organizations. Militaries should seek to involve external developers with this debate as much as possible and should exercise meaningful oversight over all stakeholders through the use of internal guidelines or codes of conduct.

The integration of RAS involves the adaptation of all the 'DOTMLPF' categories.[14] The military should reconsider whether the doctrine covers the situations of RAS deployment, whether the training and organization of forces are sufficient to ensure that RAS is taken full advantage of, whether there is sufficient technical literacy to deal with ad-hoc technical problems, whether the facilities are equipped to repair RAS, etc. The fundamental changes that RAS might bring to (some or all of) the DOTMLPF-elements require broad interaction with stakeholders within the defense organization, with international military partners, and possibly with other partner agencies.

8.3. *Considerations for CD&E*

The introduction of RAS within the Armed Forces constitutes more than just getting used to and working with new weapon systems. To be at the forefront of quickly changing needs and emerging technologies and to be able to make the right decisions on how RAS enhance the army, experimentation is key. For developers of equipment, the military world can be rather new and given new issues arise when working with RAS, intensive working relations with developers, producers, knowledge institutions, and of course the operational users themselves have to be organized. These working relations and the discussions that follow should be established for products that are almost ready, but also especially for the Armed Force's most conceptual ideas. These discussions could take place in so-called 'testbeds'.

Within the Armed Forces, the culture of how to shift from the current and planned force towards the future force requires an attitude change. In-depth conversations and research needs to take place, not only on topics of certainty, such as updating older equipment but also on uncertainties such as thinking about capabilities that will be required in the future and strategizing on how to reach that point. The defence planning system needs to be adapted for this and may also require a separate innovation fund within the Defence Investment or Lifecycle Plan. First and foremost, the strict rules on procurement will need some tweaking in order to allow for an innovative transition from older means to new ones. One possible approach could be to form a working group at the early stages of defining new demands for capabilities, where all players concerned, from legal teams and acquisition support to the operational user and the responsible staff officer can converse and plan for the acquisition of new capabilities.

Interviews found that quite a few innovations stem from the lower levels of the organization, rather than being the product of a bigger picture thinking on future technologies. Innovation departments should provide for flexible procedures and a certain level of freedom to maneuver in order to allow for 'grassroots' innovation. Innovation competitions are another good example of how the organization can rather quickly and without complex procedures reach certain innovative solutions. Also of importance is the idea that innovations are allowed to fail and that in such a case, nobody has to be punished for such failure. Though it cannot be expected for military organizations to have the same acceptance of failure and appetite for risk that can be found in industry, a shift must occur toward this attitude if progress is to occur. Failure and risk are inalienable components of true innovation. So, both industry and the military must work closely together and evaluate innovations during the life cycle of RAS technologies.

[14] Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities.

Figure 8. 13 Light Brigade RAS CD&E-unit during filming for the documentary film Robotization in the Dutch Army, taken by HCSS.

9. 13 Light Brigade RAS - CD&E-unit

9.1. *Start differently*

The common way to start a new project or create a new unit within many armies is through thorough planning, studies, and a lot of patience. In 2018 the Royal Netherlands Army Command deviated from this track and assigned an officer to start the RAS expedition with just a single informal order to "just get started and explore the possibilities". Without the normal breakdown structure of an organization and job descriptions, the officer gathered people around him with mixed expertise and conducted a brief literature review and a market survey to examine the possibilities and availability of equipment. This newly formed team got the name the RAS experimentation unit. The unit is responsible for concept development and experimentation in the field of RAS and exploring short term and midterm research objectives together with industry and universities.

This swift start made it possible to establish a team of approximately 20 people with a variation of robots, drones, and other equipment in just two years. In this period major exercises in Scotland and Austria were executed in which the RAS team took part with its robots.

9.2. *Execution*

The wise decision of the army command was to situate the RAS experimentation unit within an operational brigade, the 13 Light Brigade, instead of an education and training unit or at a centre of excellence. By doing so, it made it possible to experiment for and with the end user and receive direct feedback from those who must operate these systems in the future. The end user is represented by a regular infantry platoon which was assigned by the brigade commander as the dedicated platoon to execute the experiments. This so-called RAS-platoon is placed under the tactical command of the RAS-experimentation-unit.

In the first year and a half, the RAS-unit grasped every opportunity to make a fast start which resulted in a wide variety of projects diverging into all directions with no clear cohesion between them or obvious focal point. This way of working was a deliberate choice, to be very flexible in exploring the broad field of RAS within a short period of time and pick low hanging fruit instead of being hampered and bound to a rigidly defined path. The result of this approach, which saw many small successes in a short period of time, was that it created a positive movement and enthusiasm within the organization to embrace this programme and continue to allocate money and resources for a relatively undefined programme with an uncertain outcome. It created attention, believers, and 'sponsors' at the higher commands with the positive outcome of promoting this programme to be one of the main spearheads in the innovation of the Armed Forces.

Based on the knowledge and experience of the past year and a half, the broad and diverse approach converged into three lines of operation for 2021 and 2022. The objective of the first is to have an operational experiment in a military relevant environment, like a mission, at the end of 2022 with the RAS-platoon. The second is the continuation of the short cyclic experiments already started and the third is the (in house) development of Artificial Intelligence to make the step from remote controlled to more autonomous systems. All three lines of operation will focus on combat functions. Although it would be less controversial to start with logistics or sensing it is the state's monopoly to use force and hence has the responsibility to initiate well controlled and accountable research and development in this area. Where in the other fields of research dual use is possible, the army should adopt and incorporate these findings with a minimum of capacity to make them military proof. In the case of combat functions, specific military domain knowledge is needed in close cooperation and combined with technical expertise from industry and universities.

9.3. *Preconditions and challenges*

The degree of success of the chosen approach described above is dependent on certain preconditions and the way they are met. The following factors turned out to be crucial for the swift first phase of the RAS-project.

First, the person that is assigned to lead the project must have a rebellious and entrepreneurial mentality, especially in a large bureaucratic organization like an army. This is necessary in order to move the organization from A to B in an unconventional manner. If done in the traditional way you might end up doing things only just a bit better. Second, the project leader must show perseverance and courage because it will be a tough internal journey in which the team will encounter a lot of reluctance, inflexibility, and conservatism. Third, the management must show full confidence in the project leader and support the mission with honest intent, not with a timetable. This means that the management, one and two levels up, must accept the feeling of chaos and of being "out of control". Thus, it is important to give full responsibility at the lowest level possible within the organization. For example, in the beginning of the programme just a few projects and activities were set-up and known about by the higher command. But in time the RAS-unit grew and with it the number of projects and activities. The tipping point occurred when the higher command and above were too often “surprised” by the number of projects they were unaware of and when they were “confronted” with the scale of progress. Although all projects seemed to be in line with the programme and commanders’ intent, the unknown was uncomfortable for higher command. It took some time and many “coffee machine meetings” to prevent tightening the rules and increased control measures. To increase the situational awareness at the higher command it was agreed to introduce some kind of Liaison within the RAS-unit.

The feeling of being out of control is partially driven by the fact that the RAS programme is a complex, comprehensive, and technically driven programme. It has a wide variety of underlying projects differing in field of technology, maturity level of the engineer or concept, industrial partners, and method of approach. All these smaller and bigger projects running parallel and/or serial in time, contribute in the end to the agreed objective. But it takes an in-depth knowledge of all these projects and a holistic view to see this interconnectivity. Seeing only parts of this complex puzzle gives the impression of chaos. However, as higher command realized, having a very brief overview of the programme details but a clear view and grip on the goals and objectives is the first step. The next step is to accept this brevity of detail and suppress the first reaction to try to get grip on all the details, this is still an issue within the programme. A possible solution to tackle this concern among higher command is to create a large sequence of images in which all the (sub)projects are visualized around the main objective and the relations between these (sub)projects are outlined as well. With such an illustration it is easier to convince and inform the higher command of the necessity of these (sub)projects and that they all have their purpose within the bigger picture. Finally, for everyone involved in the programme, it is important to accept (or better embrace) failure and be patient.

9.4. *The Way ahead*

With the focus on combat for RAS development, a programme for long term investment in unmanned ground vehicles (UGV) and artificial intelligence (AI) has been initiated at the Ministry of Defence. With a horizon of 15 years, the army will invest in experimentation in a wide range of combat UGV’s including the further development of the corresponding AI. With this investment focusing on company level, experiments will be executed to develop new concepts of operation for larger scale units like a battalion or brigade a simulation programme will also be set up at the same time. The first steps of this development started in 2022 and will continue in 2023. The goal is to create a simulation environment in which a commander and his staff can experiment with new concepts of operation with the freedom to incorporate all kinds of RAS besides already existing equipment in service of the army. In addition to the concept development, the results of these simulations will provide guidelines for the formation and setup of new units, the required mix of RAS within these units, and specific qualifications for these systems.

Figure 9. NLRA, RAS-Platoon. Themis RC robot during an CD&E exercise in Austria with Dutch infantry. Ministry of Defence.