DIGITAL INFANTRY BATTLEFIELD SOLUTION

RESEARCH AND INNOVATION

DIBS project

Part III

Editors

Uģis Romanovs

Māris Andžāns

MILREM ROBOTICS

March 2019

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The book consists of a collection of opinions by authors from different countries and with diverse research backgrounds, building on the first two volumes of this project with a multi-faceted review of the development of unmanned ground vehicles (UGVs) in military use. This volume analyses initiatives of the European Union aimed at the digitalisation of the battlefield through research and innovation, as well as the defence research and innovation ecosystem in the Baltic states. It also considers the state of play of development of UGVs in selected countries.

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The opinions expressed in this book are those of the authors and do not necessarily reflect the position of any of the partners, any governmental or other entity. Authors are solely responsible for the contents of their articles.

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FOREWORD

Maj. Gen. Andis Dilāns,
Commandant of the Baltic Defence College

The future battlefield will be characterised by three major factors. Firstly, it is inevitable that the volume of the non-military aspects impacting the military operations will continue to grow. For example, the fight for the superiority in the information domain already is and will be as important as the superiority in other domains of the operation. We can expect that the tools of information warfare will be extensively used to interfere with the democratic processes of the states and to shape the opinions of the societies to ease achievements of the strategic/operational effects. It falls in line with the commonly recognized saying: "who owns the information, he owns the world"; however, in the contemporary environment in order to have an effective ownership of the information one must make sure that the institutions and people know how, with whom, and when to share the information as well as how to interpret the information received.

Secondly, with the volume of information constantly increasing, the need for information technologies (IT) capable to collect, receive, process, and disseminate the information is growing as well. This factor has opened the digital domain for military operations. The operations in the digital domain with the purpose to influence the opponent's security situation is not a new phenomenon. Cyber-attacks were effectively used to impact national elections, to shape public opinion through using social media, and to attack or infiltrate critical infrastructure such as banking systems, energy grids, governmental agencies, etc. Digital battlefield "has become a force multiplier" with rapidly developing new discoveries supporting the capabilities required to meet the challenging enemies of the XXI century.[1] Military personnel will be exposed to a variety of IT solutions as well as the challenges associated with reliance on the IT solutions to master the information.

Thirdly, the technology is changing the environment we live in, and the same claim applies to the battlefield. The biggest impact on the way the wars are waged will be due to Artificial Intelligence entering the military world. It is a matter of time before one of the technology giants will take AI to the finish line. AI will be able to generate an unprecedented number of solutions in the fraction of a second thus fundamentally changing military decision-making. Furthermore, technologies gradually replace the humans on the battlefield as the number of combat functions performed by the machines and robots is increasing over the years. One of these technologies that will soon become a common item of the modern battlefield is the unmanned ground vehicle (UGV).

The military unmanned vehicles concept is not new and there have been constant attempts to robotise armed forces and replace humans. There are a number of good reasons for that. Ronald Arkin is suggesting that "robots not only can be better than soldiers in conducting warfare in certain circumstances, but they also can be more humane in the battlefield than humans."[2] Ralph Peters is recognising their role in urban warfare – "robotic systems push deeper into the urban area, followed by armoured reconnaissance "moving fortresses" or combination of separate vehicles, delivering fire power and dismountable forces to hostile zones."[3] There are many reasons for UGVs to become an integral part of the battlefield – they are force multipliers, they expand the battlespace and extend a warfighter's "killing" and recce reach, they reduce casualties, especially in dangerous or contaminated combat zones.[4] There is one more important aspect why unmanned systems could be recognised by politicians and commanders as "less expensive, more dependable means to enhance military effectiveness"[5] enabling fewer casualties in a combat environment – because these are very sensitive topics influencing domestic politics by shaping support of the public opinion for ruling elites. Also, the industry behind the innovation supports this narrative by promoting sells of their new war tools though exploitation of noble reasons such as promises of reducing the loss of the soldiers and civilians and eliminating collateral damage.

On the contrary, there is number a of hurdles, which will slow down the pace of UGV development and, particularly, the integration of these systems into the military structures. Firstly, integration will require a significant review of the military doctrine and a conceptual understanding of how to use them on a battlefield. For example, the Australian Defence Forces are considering "developing innovative networked sensor technologies and testing autonomous unmanned vehicles to offset the small size of their military;" they are "testing network communications that will allow one operator to control a formation of unmanned aerial vehicles that can be programmed to peel off independently for surveillance, or to launch an attack."[6] If this ambition is achieved, it would trigger a significant revision of the military doctrine, concepts, and procedures.

Secondly, there is a number of operational limitations when it comes to the application of the UGVs in the battlefield. Having a closer look at the current systems, we can see that there are no truly unmanned ground vehicles, as there are operators controlling them from a distance via remote-control devices. There is also a need for additional resources to protect these systems while they are employed on the battlefield in order to make sure that UGV is not lost and the mission is accomplished.

And finally, before implementing unmanned systems into the battlefield, development of a new set of the legal and ethical regulations is required, particularly for using autonomous weaponised robots against human targets. The latter aspect is of great importance because there are serious moral dilemmas regarding unmanned systems. „If the military keeps moving forward at its current rapid pace towards the deployment of intelligent autonomous robots, we must ensure that these systems be deployed ethically, in a manner consistent with standing protocols and other ethical constraints."[7] This is just to mention that it is estimated that during the first five years of president Obama's administration drone attacks caused the death of as many as 2400 persons,[8] including civilians. Even more, such strikes could "violate the national sovereignty of the nations where they are used; constitute targeted assassinations that are illegal under international law; and be responsible, even regardless of how far terrorists and insurgents may constitute legitimate targets, for also killing many innocent civilians."[9] Christopher Coker assumed that "until 2035 most robots will be autonomous but probably unable to make a cognisant judgment, but they certainly will be able to act at their own discretion, to select targets according to their will, and even to reject people as decision-makers. It will have impact especially on tactical level of war but both operational and strategic decisions will be taken by people."[10] Furthermore, the device definitely is not cheap. The price of a weaponised unmanned ground system can reach as much as several hundred thousand Euros. Needless to mention that the deployment and employment of UGVs in a combat zone requires transportation and logistics.

Introduction of such expensive and experimental systems into the inventory of small nations such as three Baltic states represents a challenge and it is rather impossible due to their limited defence budget, as well as the urgent need to close essential military capability gaps. Particularly when comparing opportunities of the small states with the ambitions and opportunities of the large nations, the chances to evolve in the field for smaller nations look rather marginal. For example, the USA-planned Army's Robotic and Autonomous Systems Strategy in the 2016–2020 Programme Objective Memorandum (POM) alone is funded with $770 million.[11] Just lately, in August 2018, President Trump authorised the USA Department of Defence to spend $9.6 billion in the fiscal year 2019 for unmanned vehicle systems.[12] Lately Russia has been active with the modernisation of armed forces aiming to "spend upwards of $9.2 billion on UAVs through 2020. This was up from $8.8 billion Russia intended to spend through 2020."[13] China is not far behind, being a recognised investor in R&D sector and in just 2016 alone with some $390 billion[14] and it "has ambitions to compete in the big market—to directly compete against the United States and the Europeans and the Russians with high tech products."[15]

Nevertheless, the abovementioned facts should not be seen as an obstacle for the defence industry companies of the small states to participate in the defence research and innovation efforts. Even more, in the current global security environment, small states' finance and defence policies have to promote defence-related innovation projects in order to facilitate cross-sectoral collaboration, establish international business networks, and consequently function as a catalyst for the state's economic growth. Recent EU initiatives improve the ecosystem for contribution to the defence sector development. European defence was identified as one of the key priorities for the EU in 2016.[16] The European Commission's initiative to create the European Defence Fund could be considered as an enabler for enhancing the cooperation among member states in the defence sector. More importantly, it provides an opportunity to foster collaborative research and the development of innovative defence products and technologies. While the Commission emphasises the strengthening of the competitiveness of the EU defence industry, which should eventually lead to the EU's strategic autonomy,[17] the success of this initiative depends on the political will of the member states to cooperate in the defence sector. So far, the defence has been viewed as a national prerogative by member states; therefore, cross-border cooperation is limited, and it includes unmanned platforms' market as there are strong national interests supported by powerful military industry lobby in the respective countries. It contributes to the existing fragmentation of defence markets, unnecessary duplication, and lack of interoperability between the capabilities of the member states.[18] This existing fragmentation in European defence markets restricts the possibilities for the European defence industry to be competitive at the global scale. The European Defence Fund without a doubt will contribute to defence research by offering €13 billion to fund research and the development of capabilities.[19] This could potentially lead to the development of innovative technologies in the defence sector. Nevertheless, further investments of the member states in defence research and innovative technologies are crucial in order to strengthen the competitiveness of the European defence sector. Whilst the Commission emerged as a new player in European defence, its role in defence remains constrained by national prerogatives of the member states. Thus, the member states play an important role in defining the priorities of defence capabilities, which would contribute to the European defence.

All factors of the future battlefield will trigger fundamental changes in the military doctrine, training, equipment, capabilities, structures, affecting nations across the world. Consequently, this requires a revision of the key competencies of the military personnel. Professional Military

Education (PME) institutions, being at the pinnacle of change in the military thought, must put greater emphasis on the skills, knowledge, and attitudes enabling military professionals to feel confident when confronted with the challenges of the digital battlefield. As an outcome "as the soldiers and leaders became more familiar with the technology and its use, they became less threatened by it, and appreciate more the positive impact it would have on them, their units, and the Army as the whole."[20]

It is of utmost importance to incorporate aspects discussed in this foreword into the curricula at all levels of the military education, as well as the exercises. In other words, PME institutions have to enable their students to do both – to study the wars fought in the past and model and define the characteristics of the possible future security environment and prospective war scenarios. This requirement calls for close cooperation and partnership between PME institutions and organisations leading the defence research, innovation, and development. Furthermore, such cooperation would serve as a catalyst for defence innovation and research, as PME institutions usually represent a hub of military expertise and knowledge, which is required for keeping the defence innovation projects relevant and focused.

This book – "Digital Infantry Solution. Research and Innovation" – is a small, but an important contribution to our preparedness to cooperate, look into the challenges of the future battlefield, and be better prepared for the future to come.

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INTRODUCTORY REMARKS

Uģis Romanovs and Māris Andžāns

The emerging technologies function as a catalyst for changes in the security environment. In the past, there have been numerous occasions when technologies have triggered evolutionary leaps in the ways of waging wars. This book addresses one of the very topical emerging technologies of modern warfare – the unmanned ground vehicles (UGVs). The book follows the first two volumes of the project – *Digital Infantry Battlefield Solution: Introduction to Ground Robotics. DIBS project. Part One* and *Digital Infantry Battlefield Solution. Concept of Operations. DIBS project. Part Two.*

The first volume of this project, published in December 2016, provided a retrospective and prospective analysis of the development of UGVs, also addressing current issues and challenges in using them from tactical, technical, and legal perspectives. The second volume, published in August 2017, provided an analysis of ethical and legal aspects of the employment of UGVs, taking a closer view on how certain countries have developed and are progressing with their UGV capabilities. Among the countries considered in the second volume were the People's Republic of China, Israel, Poland, Russia, Ukraine, and the United States. In March 2019, the first two books were named second prize winners of the Latvian Defence Industry Award in Education and Research.

This volume takes a step further in considering the use of UGVs. First, Kristina Prišmantaitė provides an analysis of the EU initiatives aimed at the digitalisation of the battlefield through research and innovation. Ieva Bērziņa offers a comprehensive assessment of the defence research and innovation ecosystem in Estonia, Latvia, and Lithuania.

The second part of this book considers the state of play of development of UGVs in selected countries. The chapter on Canada is authored by Yazan Qasrawi, Abdeslem Boukhtouta, and Peter Gizewski, on France – by Gérard de Boisboissel, on Germany – by Mirosław Smolarek, on the United Arab Emirates – by Sintija Broka and Serge Lévitski, on the United Kingdom – by James Rogers and Robert Clark.

This book is a result of collaboration between Milrem Robotics, Baltic Defence College (based in Estonia), Centre for Operational Research and Analysis at the Defence Research and Development Canada, General Tadeusz Kościuszko Military Academy of Land Forces (Poland), Latvian Institute of International Affairs, Latvian National Defence Academy, Military University of Technology (Poland), Rīga Stradiņš University (Latvia), and War Studies University (Poland).

Technological progress is essential for the military sector. Let us reiterate that outmoded warfighting methods and technologies of the past can be applied if the opponent uses similar methods and technologies. But the failure to keep up with technological developments can considerably reduce any resistance capabilities and abilities. UGVs are not in the distant future anymore. They have become a mainstream necessity of modern armed forces, and their importance is yet to increase.

RESEARCH AND INNOVATION IN THE DEVELOPMENT OF UNMANNED GROUND VEHICLES: THE EUROPEAN UNION AND THE BALTIC STATES

BATTLEFIELD DIGITALISATION THROUGH RESEARCH AND INNOVATION IN THE EUROPEAN UNION

Kristina Prišmantaitė

The changing European security environment and emerging new security threats reminded the Europeans of the need to take responsibility for their security. The European Union (EU) has introduced a number of new initiatives which are crucial to strengthening European security and defence. In addition, in 2016, the European Commission (hereinafter Commission) adopted the European Defence Action Plan that emphasised the need to foster competitiveness and innovation in the defence industry of Europe.[1] In 2013, the EU had already highlighted the importance of investment in research and innovation by stating that the lack of the investment posed "a threat for the long term competitiveness of the European defence industry and Europe's defence capabilities."[2]

In accordance to the objectives and priorities set in both the EU Global Strategy (EUGS) and the Defence Implementation Plan, such new initiatives as the Permanent Structured Cooperation (PESCO) and the European Defence Fund (EDF) establish the cooperation frameworks for member states. These cooperative frameworks could be considered as enablers for the development of military capabilities of member states. One of the EU's development priorities is innovative technologies for enhanced future military capabilities which would allow the EU to achieve its level of ambition.

The EU policies and legal documents related to the EU defence research and innovation policy create incentives for promoting defence research, innovation, and the development of advanced technologies. The investments in research are crucial to developing innovative technologies which are necessary for the digitalisation of the battlefield. The article will introduce the EU's priorities in defence and research, followed by the assessment of the current EU policies and activities.

RESEARCH AND TECHNOLOGY

Importance of research and technological progress is stressed in the Treaties of the EU. For instance, according to the Article 4.3 of the Treaty of the Functioning of the European Union (TFEU), "in the areas of research, technological development and space, the Union has competence to carry out activities, in particular to define and implement programmes; however, the exercise of that competence shall not result in Member States being prevented from exercising theirs."[3] This means that the EU shares the competences with member states regarding research and technological development. Not only did the Commission identify the EU's leadership in innovations and integrating emerging technologies as challenges, but it also launched the Digitising European Industry Initiative in 2006 (as part of the Digital Single Market) which aimed to strengthen the competitiveness of the EU in the digital technologies.[4] Digital technologies have an important role in the defence sector as well, therefore it could be argued that new developments of advanced technologies may eventually lead to the digitalisation of the battlefield. Alm et al (2016) define digitalisation as a "transformative shift in technology across industries and society in general."[5] In other words, digitalisation refers to the transformation process which is influenced by the new technologies. However, this process requires large investments. In the case of the EU, the expenditure on defence research and technology (R&T) continues to decrease, and in 2016 it only amounted to just below €1,6 billion which is significantly below the Collective Benchmark of 2% to be spent for R&T of the total defence expenses (as agreed by European Defence Agency (EDA) and EU member states in 2007).[6] As the EUGS emphasises the necessity to enhance its credibility in security and defence, the investment in R&T is identified as instrumental in developing defence capabilities and meeting the commitment of 20%

of the defence expenditures to be spent for both the procurement of equipment and R&T.[7]

The investments in R&T programmes are crucial to developing military capability. Due to the low investments of EU member states into defence research, the initiatives on launching the EU programmes related to defence research came from the EU institutions which could be viewed as enablers for fostering defence research and innovation programmes where member states would be the main beneficiaries. Until now, defence research and development programmes were almost exclusively managed at a national level. Considering the cost of advanced defence technologies as well as the need to maintain a full spectrum of armed forces, cooperation in defence within the EU framework is inevitable. European countries face shortcomings in capacities and capabilities when it comes to their national armed forces. As a result, new EU initiatives in the area of defence aim to address the existing shortcomings that affect the ability to retain a full spectrum of national forces. The EU identified the lack of defence innovations as problematic because of the declining cooperation in defence research and development (R&D) and investments in equipment which affect the ability of the EU to develop new systems and technologies as a whole.[8] The changing security environment and operational challenges trigger the requirement for European countries to invest in the development of more responsive and mobile forces. Furthermore, technology innovation is essential in developing operational capabilities. Therefore, the investment in new technologies through the EU platform will allow member states to invest in technologies together, which will lead to greater cooperation between the countries, including greater interoperability.

The EU's investment in defence research, innovations, and technologies are closely linked to the capability priorities that were identified in the Capability Development Plan (CDP) in 2014. The identified defence capabilities priority areas were: "Intelligence, Surveillance and Reconnaissance, Remotely Piloted Aircraft Systems, satellite communications, and autonomous access to space and permanent earth observation; high-end military capabilities, including strategic enablers; cyber and maritime security."[9] Meanwhile, the 2018

CDP also includes the R&T dimension and identifies the shortfalls and opportunities of research activities and the current state of the European defence industry.[10] As the Commission puts it, "defence research is essential to develop the future key capabilities, bridge technological gaps and thereby address emerging and future security threats facing Europe."[11] The EDA has identified that the "technologies that may enable Member States forces' ability to operate in the future strategic environment are human enhancement (biological, cybernetic, other) technologies, sensors, artificial intelligence, synthetic environments, virtual reality and augmented reality, smart/complex materials, satellites and pseudo-satellites, autonomous systems (incl. manned–unmanned teaming), communication systems, additive and advanced manufacturing, nanotechnology, DEW [directed-energy weapons], EW [electronic warfare], ECM [electronic countermeasures] and energy generation and storage."[12] It is important to note that the defence industry heavily depends on research. The new technological solutions (from artificial intelligence to robotics) can boost innovation in the defence sector, therefore the promotion of synergies between civil and military sector is crucial for strengthening the defence industry of the EU, which is a necessary step for establishing the so-called European strategic autonomy.

IMPLEMENTING DEFENCE RESEARCH: EU POLICIES AND ACTIVITIES

Article 173 of the TFEU provides the legal base for "fostering better exploitation of the industrial potential of policies of innovation, research and technological development."[13] The European Commission has played a significant role in fostering research and innovation projects under the EU Framework Programme for Research and Innovation (Horizon 2020). The current framework restricts EU funding to civilian or dual-use R&T only. For this reason, the Commission proposed an initiative for a future EU defence research programme in order to address the EU's level of ambition.[14] Nevertheless, the EU emphasises the necessity for synergies between civil and defence sectors given that they increasingly overlap. Taking into account that new technologies are an integral element of innovation in both civilian and military industries, the "defence industry's dependence on technologies with civilian origin is increasing."[15] Therefore, it is anticipated that the results of the research under the current research and innovation programme would also contribute to the development of defence capabilities. Defence research will fall under the scope of the next Research and Innovation Framework Programme – Horizon Europe – which will succeed Horizon 2020. Horizon Europe sets new priorities for the European Research and Innovation policy. For the next long-term EU budget of 2021–2027, the European Commission has proposed €100 billion euros for research and innovation.[16] Horizon 2020 could encourage spill-overs of research and innovation from the civil sector to the defence sector. Thus, the collaboration between the defence industry and civilian innovative industries will be inevitable under the new Multiannual Financial Programme.

European Defence Action Plan, introduced by the European Commission in 2016, oversees the potential of defence research in relation to innovation and technology. More importantly, the Plan identified the instruments needed to support the defence industry and development of capabilities that could meet current and future European security needs. In accordance with the identified objective, the establishment of a European Defence Industrial Development Programme (EDIDP) is aimed at enhancing competitiveness and innovation of the defence industry in the EU is proposed. The use of the results of defence research is closely linked to the enhancement of defence assets.[17]

The EU aims to invest more in defence R&T programmes in order to develop military capabilities of member states. The establishment of a European Defence Research Programme as part of the EU's next Multiannual Financial Framework (2021–2027) will be an important step in strengthening the EU's capacity to invest in defence R&T. As a preparation for the launch of the EDF, the decision was made to launch a defence-related Pilot Project in the EU budgets of 2015 and 2016. The

European Defence Agency (EDA) received the responsibility for the project's execution and management based on the agreement signed between the EDA and the Commission. The proposed budget for the Pilot Project was €1.4 million to be used for covering three specific areas: development of unmanned heterogeneous swarm of sensor platforms (EuroSWARM), sensor platform & network for indoor deployment and exterior-based radiofrequency (SPIDER); traffic awareness (TRAWA).[18] The Pilot Project was viewed as a crucial step for further development of defence research in the EU. Its purpose was to "test the conditions for defence research in an EU framework."[19] It also paved the way for the next milestones towards defence research and the inception of the Preparatory Action on Defence Research (PADR).

The PADR was launched in 2017 in order to explore the potential of a Europe-wide programme of research covering security and defence areas. More importantly, the aim of this programme is to demonstrate the added value of the EU's contribution by complementing the civilian research conducted under the Horizon 2020 programme. The Commission allocated €90 million from the EU budget for the period 2017–2019 to implement the projects on the defence research.[20] The Commission imposed certain restrictions on funding under the PADR by clearly stating that funds could "only be used for R&T activities related to defence technologies, products and systems, but not for military operations."[21] The PADR includes three main topics: "a technological demonstrator for enhanced situational awareness in a naval environment" (the added value of unmanned systems in enhancing situational awareness); "research in technology and products in the context of Force Protection and Soldier Systems; strategic technology foresight" (to develop scenarios of potential future conflicts which will help scoping EU-funded defence research).[22] The research projects were identified by the EDA together with member states and the Commission. The Ocean2020 project is one of the projects that received a €35 million grant. This "project supports maritime surveillance and interdiction missions at sea and to that end will integrate drones and unmanned submarines into fleet operations."[23] This project is expected to boost research in the naval area.

The Pilot Project and the PADR are set to prepare the launch of the European Defence Industrial Development Programme (EDIDP). The lessons identified during these initial phases will contribute to the set-up of the EDIDP. It is important to underline that the initial funding under 2014–2020 Multiannual Financial Programme was allocated for two programmes: a PADR (which supports collaborative defence research) and an EDIDP (which co-finances collaborative development projects).[24] These programmes serve as initial tests of collaboration in defence R&D projects before the launch of the EDF. The PADR and the EDIDP will provide an important incentive for both research and capability development in the area of defence. The Commission has developed guidelines regarding the future defence research projects that emphasise the capability-driven research with a "focus on critical defence technologies as well as exploratory and disruptive research" which should "potentially strengthen the technological leadership of the European defence industry."[25] Meanwhile, the Implementation Plan suggests that one of the most significant steps to build Europe's resilience is the promotion of technological innovation and defence investment.[26]

The civil and military synergy across different fields of EU policies requires the synchronisation of different funds and programmes in order to avoid further fragmentation and duplication. For example, the EDIDP will need to be developed in synergy with other initiatives such as PESCO. Furthermore, the Commission aims "to ensure synergies with other EU initiatives in the field of civil R&D, such as security and cyber security, border control, coast guard, maritime transport and space."[27] EU member states will be able to use European Structural and Investment Funds (ESIF) in the defence sector, though under certain conditions: first, that productive investment projects are co-funded and, second, that modernisation of supply chains in the defence sector is supported.[28] In addition, the European Regional Development Fund (ERDF) can also be used to financially support defence, as well as dual-use activities when it comes to research and innovation.[29]

STRENGTHENING EUROPEAN DEFENCE: ENABLERS AND CONSTRAINTS

The European defence sector is facing such issues as the low level of investments and fragmentation resulting in unnecessary duplications. The cross-border cooperation, which is advocated by the EU, would contribute to the development of technologies by reducing duplications and increasing investments in defence research and capability development. The launch of the EDF could be viewed as the driving factor for defence research and innovation in Europe. A budget of €13 billion for 2021–2017 will be dedicated to the EDF, which will make the EU as one of the top four defence research investors in Europe. The EDF consists of two windows – research (€4.1 billion) and capability (€8.9 billion) – "which would cover the entire cycle of defence industrial development."[30] The EU will finance the total costs during the research phase and will complement member states' investment by co-financing up to 20% of the cost for prototype development and up to 80% of the ensuing certification and testing activities.[31] However, the EDF will not cover the acquisition phase, which will be financed from member states' budget. The key restriction for receiving funding from the EDF is the commitment of member states to buy the final product because the EDF will only co-finance the development of common prototypes.[32] The Commission's decision to fully fund defence research projects demonstrates that research is crucial to the development of advanced technologies as a part of capability development in security and defence. Therefore, low investments in research by member states would be somewhat compensated by the EDF which will contribute to the strengthening of Europe's strategic autonomy. Such collaborative efforts in defence research will promote further defence cooperation that could eventually lead to the deepening of defence cooperation with more commitments in European defence demonstrated by member states.

The EDF will contribute to Europe's strategic autonomy, one of the key objectives identified in the EUGS, and will foster innovation solutions. It will also contribute to strengthening the resilience of the defence sector and addressing its vulnerability in order to respond to complex security threats. One of the constraints of the EDF is that the EDF will only offer funding for those capabilities that are commonly agreed by member states (i.e. identified defence capability priority areas) within the framework of the Common Defence and Security Policy (CSDP) and with recognised EU added value. Furthermore, member states will still be responsible for the sustainability of investments in the defence sector and for launching capability development programmes.[33] Therefore, the development of the European defence industry depends on member states which might not be willing to commit to a full cycle of capability development.

Successful implementation of future European defence programmes will require a constant consultation between the Commission, the EU member states, the European Parliament, EDA, the European External Action Service, and the industry. Accordingly, one of the central issues is the establishment of governance for the management and implementation of the programme. It is important to note that the establishment of the EDF enhances the Commission's role in defence as it clearly views the coordination of research and innovation programmes as its key responsibility.[34] Nevertheless, well-established governance will be required in order to implement the programmes under the EDF.

One of the main prerequisites for the success of the European defence sector is personnel with skills required to provide the European defence sector with a competitive edge.[35] Thus, the EU will have to develop strategies of mitigating the existing skills shortages by both retaining personnel with key skills and recruiting qualified experts. Another issue that requires attention is deciding on the priorities of research, intellectual property rights, funding, confidentiality, and rules of participation, etc. These issues add more complexity to the implementation of defence research programmes under the EU funding. These issues need to be carefully considered in order to remove barriers for cross-border cooperation.

CONCLUSION

The investments in defence research will create an added value to the innovativeness of the European defence industry, that would lead to the development of advantaged technologies necessary for armed forces. It is important to underline that the programmes funded by the EU are not aimed at substituting national investment in defence R&D. Instead, the programmes are meant for promoting defence cooperation among member states by creating synergies with national efforts in defence research. In short, the funds will be used to complement and catalyse national efforts.[36] By investing in defence research, innovation, and technologies, the EU will enable the deepening of defence cooperation, enhancement of interoperability and efficiency, the development of capabilities and advanced technologies needed for a full spectrum of armed forces. Defence research will also open up possibilities of knowledge exchange among member states.

The EU's focus on both research and capability development activities promotes an integrated approach to the whole cycle of the development of technologies. Therefore, the EU aims to reduce the space between research and development by ensuring that the results of the research will be transformed into capability development, including digital technologies that could eventually lead to the digitalisation of the battlefield. Moreover, strategic autonomy requires technological autonomy. It is also important to stress that innovation and technology development is critical in ensuring sustainability and competitiveness in the defence sector industry. Thus, the EDF will serve as a tool to foster the competitiveness of the technological and industrial platform of the European defence sector. Capability development should correspond to security challenges as well as be adherent to the future operation environment.

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DEFENCE RESEARCH AND INNOVATION IN THE BALTIC STATES

Ieva Bērziņa

The technological advancement of armaments has played a decisive role in warfare historically and even more so in the 21st century, therefore defence research and innovation has an important role in strengthening defence capabilities. This applies not only to great powers but also to small countries that may use defence research and innovation to develop specific niche areas of military technologies and to improve the efficiency of military acquisition and procurement. The aim of this chapter is to provide insight and to compare defence research and innovation development in Estonia, Latvia, and Lithuania. This study uses desk research to obtain and analyse information about this field in the Baltic states. The chapter begins with a comparative perspective of overall research and development indicators in the Baltic states because defence research and innovation is an integral part of general scientific development. The second part outlines the ecosystem perspective on defence research and innovation. Finally, the development of defence research and innovation in each country is analysed.

RESEARCH AND DEVELOPMENT IN THE BALTIC STATES

The concept of research and development (R&D) relates to the link between science and industrial production, which promotes innovation, technological advancement, and economic growth.[1] Military R&D is an important part of this field.[2] As admitted by Eric Platteau and Helmut Brüls: "...cuttingedge, high-tech innovations, including those with potential for military applications, are often driven by the civil commercial sector with start-ups and high-tech companies spending unparalleled amounts on R&T which cannot be matched by the military."[3] Therefore the analysis of defence research and innovation in the Baltic states is based on the assessment of the overall R&D trends in these countries.

One of the widely used indicators is the gross domestic expenditure on R&D as a percentage of gross domestic product (GDP) (Figure 1). According to the data of the UNESCO Institute for Statistics,[4] Estonia had the highest expenditure on R&D as a percentage of GDP in 2016 among the Baltic states, although in all countries this indicator has fallen in relation to 2015. In Estonia, the gross domestic expenditure on R&D as a percentage of GDP was 1.28%, in Lithuania – 0.85%, and in Latvia – 0.44% in 2016. To assess the level of expenditure on R&D in the Baltic states, it must be put in the global context. The highest expenditure on R&D as a percentage of GDP is in Israel and Republic of Korea, where this indicator is more than 4%, in Japan, Austria, Sweden, and Switzerland (in 2015) it exceeded 3%, but in Denmark, Finland, USA, and Germany it was close to 3% in 2016.[5] As this comparison shows, the Baltic states' investment in R&D is relatively low. Due to the relatively small size of the economies of these countries, the actual gross domestic expenditure on R&D also is limited – in Lithuania it was 729 813, in Estonia – 499 629, and in Latvia 225 164 thousand in current purchasing power parities in USD in 2016.[6]

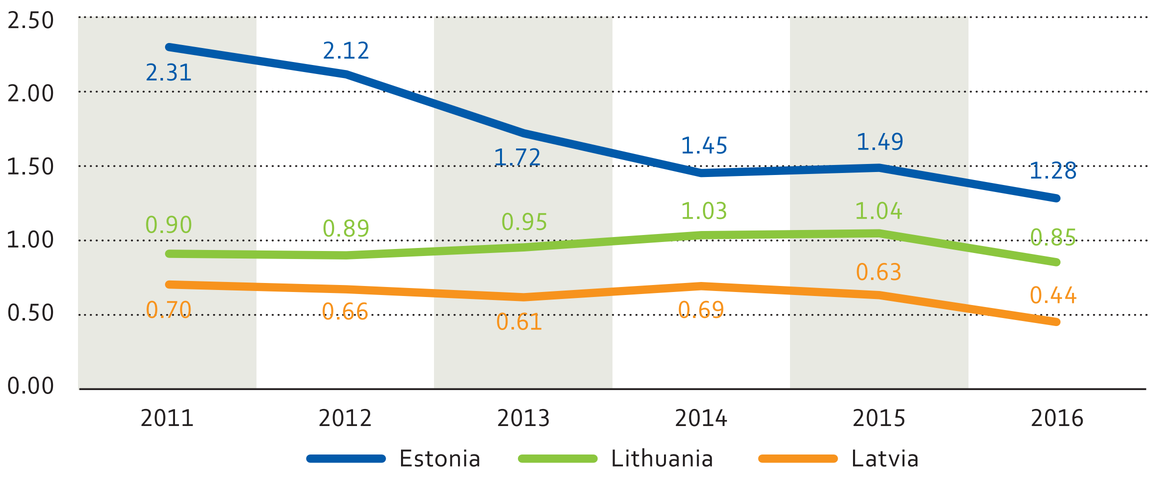

Figure 1. Gross domestic expenditure on R&D as a percentage of GDP.
Source: UNESCO Institute for Statistics.

Another indicator used to evaluate R&D in a country is the number of people being employed in this field. One of the comparative measurements is total R&D personnel per million people in full-time equivalents, which includes researchers, technicians, and other supporting staff (Figure 2). Among the Baltic states, this indicator is the highest in Estonia – 4397, which is followed by Lithuania – 3756, and Latvia – 2598.[7] It should be noted, although, that in relation to this indicator all three Baltic states lag behind countries with higher expenditure on R&D. For example, the same indicator in Denmark was 10555, Sweden – 9219, Finland – 8619, Austria – 8453, Norway – 8358, and Germany – 8017 in 2016.[8]

The expenditure on R&D and the number of people being employed in this area may be regarded as input indicators. The comparative overview of these indicators gives evidence that R&D is not a priority for the Baltic states because the investments in this area are lower than in technologically and economically more advanced countries. Of course, these are relative indicators which are affected by the size of a country, therefore the estimation of the performance of R&D in the Baltic states is being made in comparison with the Nordic countries, which are regionally close and comparable in terms of the size of the population.

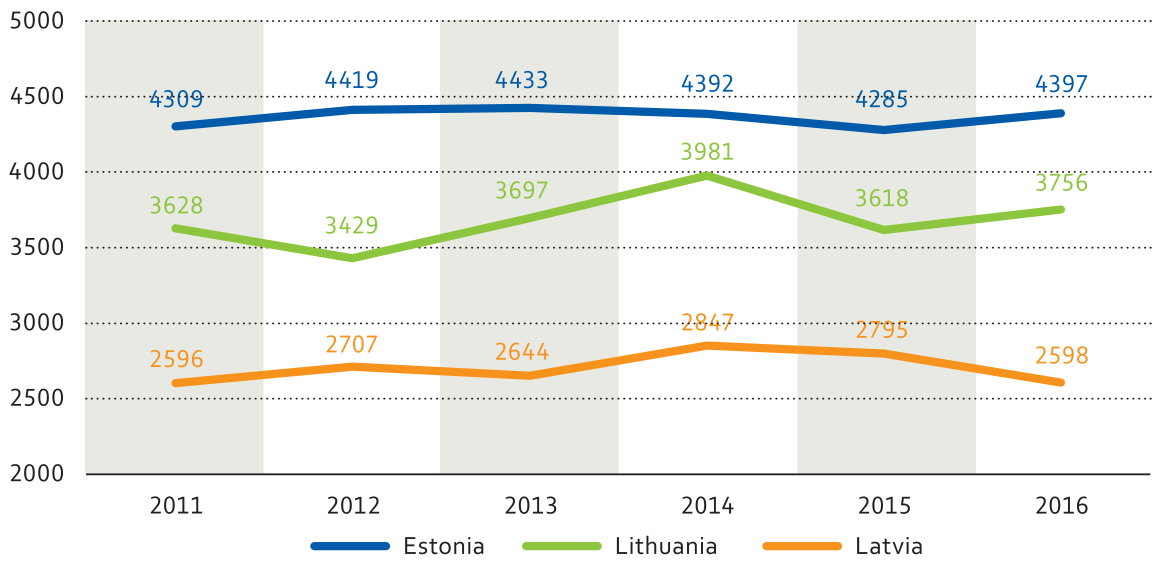

Figure 2. Total R&D personnel per million people in full-time equivalents
Source: UNESCO Institute for Statistics.

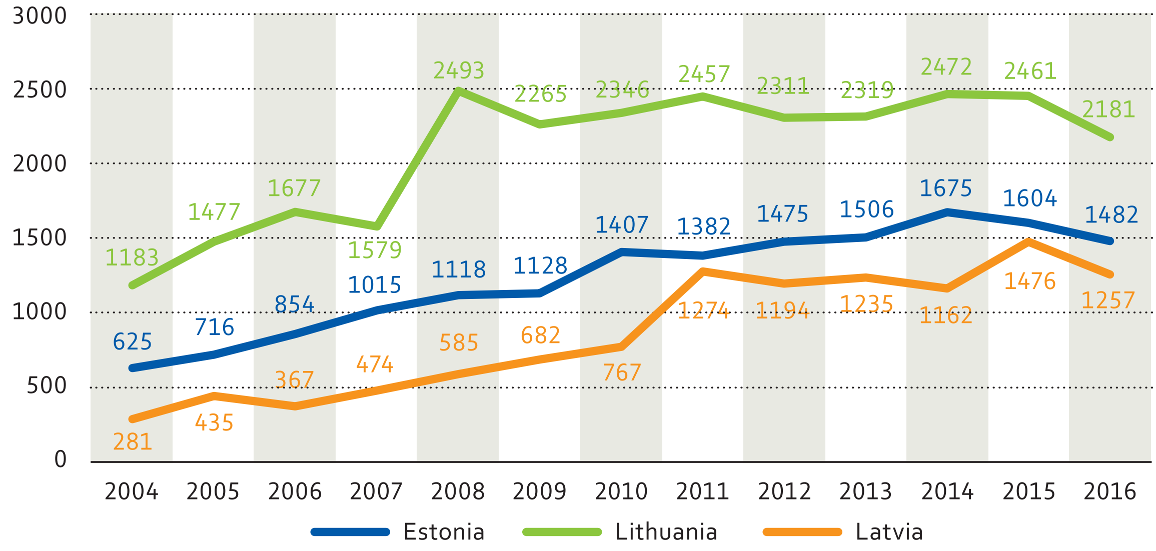

Figure 3. Scientific and technical journal articles.

Source: National Science Foundation, Science and Engineering Indicators as cited in The World Bank.

The number of scientific and technical journal articles (Figure 3) is an important indicator of R&D performance. During the period from 2004 to 2016, Lithuanian scientists published the largest number of scientific and technical journal articles among the Baltic states, which may be explained with the fact that Lithuania has the largest total number of researchers.[9] Lithuanian researchers published 2181 scientific and technical journal articles, Estonian – 1482, and Latvian – 1257 in 2016.[10] However, if the performance of the researchers of the Baltic states is being compared with the Nordic countries, it can be seen that the Baltic states form a separate group of countries with a lower performance, because researchers from Sweden published 19937, Denmark – 13471, Norway – 10726, and Finland – 10545 scientific and technical journal articles in 2016.[11]

Patent applications are yet another indicator of the R&D sector performance because it describes the number of inventions in a country (Table 1). According to the World Intellectual Property Organization data, the level of inventions is similar in all three Baltic countries, because the total number of patent applications is not more than 300 in 2016 in each of them.[12] Whereas in the Nordic countries this figure is more than ten times higher. In 2016, Sweden had 5587 resident, 352 non-resident, and 17866 patent applications abroad, Denmark – 3422 resident,

Table 1. Patent applications

Source: World Intellectual Property Organization.

	Estonia			Latvia			Lithuania		
Year	Resident	Non-Resident	Abroad	Resident	Non-Resident	Abroad	Resident	Non-Resident	Abroad
2007	57	19	57	159	8	60	71	20	30
2008	69	10	85	250	9	142	98	18	36
2009	110	20	160	289	3	214	104	16	35
2010	111	13	193	211	7	243	117	6	57
2011	92	15	183	200	10	125	107	15	35
2012	61	5	230	218	12	141	127	15	69
2013	66	17	207	305	8	175	139	20	81
2014	80	6	198	111	4	82	147	42	107
2015	62	6	174	165	1	123	140	18	135
2016	73	1	202	107	18	148	122	58	97

298 non-resident, and 8310 patent applications abroad, Finland – 3078 resident, 108 non-resident, and 9482 patent applications abroad, Norway – 1755 resident, 833 non-resident, and 4147 patent applications abroad.[13]

The brief overview of some R&D indicators gives a general idea of the context in which defence research and innovation take place in the Baltic states. According to the European Innovation Scoreboard, all these countries are moderate innovators – the summary innovation index of Estonia is 0.4, Lithuania – 0.36, and Latvia – 0.29, which is below the EU average – 0.5 in 2017.[14] It may be concluded that overall R&D is underdeveloped in the Baltic states, which constrains defence research and innovation due to limited scientific and financial capacity. However, the development of defence research and innovation in the Baltic states should be put into a wider context.

The Baltic states are a part of Europe, which, according to Klaus Thoma, is lagging behind the USA and China in terms of defence research: "...the US plans to spend EUR 64 billion on R&D in 2017.

China's yearly defence R&D is estimated at more than EUR 20 billion. In comparison, the member states participating in EDA spend all together only EUR 7.5 billion per year."[15] Thus the development of defence research and innovation in the Baltic states must be seen as a part of a European defence research development. As concluded by Frédéric Mauro: "…the only way for European countries to preserve or restore their strategic autonomy is to pull their resources together. [..] There is no alternative. Lonely roads lead nowhere."[16] This is especially true in the case of the Baltic states due to their limited R&D capacity. To develop defence research and innovation in each country and in Europe as a whole, the Baltic states must integrate in common European and Transatlantic processes by providing expertise in their areas of specialisation. To better understand the specifics of defence research and innovation in general and in each of the country, it was decided to take a broader look at this area as an ecosystem.

THE DEFENCE RESEARCH AND INNOVATION ECOSYSTEM

Successful defence technology development is a result of several interrelated factors, such as scientific capacity, funding, strategic planning, organisational culture, industrial production, collaboration, et al. Therefore, it is reasonable to use the ecosystem approach for the analysis of defence research and innovation, because it identifies the most important actors and their interrelationships in the process of defence technology development. As it was said by Ron Lloyd: "Defence innovation isn't a scientific problem. It's not a technical problem. It's not a procurement problem. It's an organisational problem. So we need to tackle it at an organisational level; we need to create a process that turns ideas into advantage as a natural part of our way of business."[17] Marwan Lahoud mentions that a specific mindset is critical for innovation: "To grasp strategic innovation, companies need swift decision making, less-risk adverse behaviour, failure acceptance, and fast spiral development cycles."[18] EDA admits there are four trends determining successful and fast innovation: "(i) global competition for the lead in technology; (ii) emerging knowledge domains and technology convergence; (iii) increasingly faster innovation loops; and (iv) the growing importance of private investment in support of innovation."[19] To meet these challenges, defence research and innovation should be viewed as a wider ecosystem that requires changes in policy-making and business models.[20] For example, Magnus Christiansson describes the third offset strategy of the USA defence planning as metagovernance, which challenges "rational planning as it entails an indirect approach of organizing arenas for networks, in which start-up companies and civilian corporations get to interact with government officials in order to identify incrementally suitable acquisition projects."[21]

Deborah J. Jackson distinguishes three groups of innovation ecosystem actors: the material resources; the human capital; the institutional entities,[22] which are the main building-blocks of defence research and innovation systems as well. The development of defence research and innovation sector is specifically determined by the interaction of two factors – military capabilities and technological advancement: "…the top-down capability-driven path – what do we need to produce the weapons we need? – and the bottom-up technology-push: what do we know from present technologies that could be used as weapons, or decisively improve weapons?"[23] Frédéric Mauro and Klaus Thoma conceptualise the defence planning process in most of the EU and NATO countries as "the strategic path" consisting of five consecutive elements: "1) planning and setting the level of ambitions – what do we want to be able to do militarily?; 2) programming the capabilities – what do we need to acquire or develop?; 3) apportioning (in an alliance) – who acquires what?; 4) implementing – budget, procure, select technologies, deliver; 5) reviewing – lessons learned."[24] Defence research and innovation should be an integral element of this planning process.

For the Baltic states as members of the EU and NATO, a significant element of defence research and innovation ecosystem is the framework of strategies, policies, funding, and regulations of these two organisations. The year 2014 was the turning point for NATO and the EU towards a more active development of defence research and innovation, which was determined by Russia's annexation of Crimea and its further involvement in the war in the Eastern Ukraine, as well as the growing awareness that the gap between the superiority of Western military technology and that of other actors in the international arena is decreasing. NATO Warsaw Summit Communiqué includes a commitment to strengthen the defence industry, to increase cooperation across alliance and within Europe in the area of military technology development, and to support innovation.[25] The EU-NATO Joint Declaration of 2016 identifies "to facilitate a stronger defence industry and greater defence research and industrial cooperation within Europe and across the Atlantic"[26] as one of the top priority activities. Among the priority tasks of the Global Strategy for the European Union's Foreign and Security Policy, adopted in 2016, it is stated that: "Gradual synchronisation and mutual adaptation of national defence planning cycles and capability development practices can enhance strategic convergence between Member States. Union funds to support defence research and technologies and multinational cooperation, and full use of the European Defence Agency's potential are essential prerequisites for European security and defence efforts underpinned by a strong European defence industry."[27] Thus the trends at the EU and NATO level are favourable for defence research and innovation development. The final sections of the chapter examine the trends of defence research and innovation at the national level in the Baltic states. They are structured around such areas as defence research and innovation related policies and strategies, organisation, and funding.

POLICIES AND STRATEGIES

To compare how defence research and innovation is incorporated in defence policy documents of the Baltic states, it was decided to use the information about national policies and strategies of defence, defence procurement, and defence industry, as they are provided in the European Defence Agency (EDA) website.[28] The study uses the EDA website, because it may be assumed that countries have highlighted the most important documents in the field, thus it provides a reasonable comparative basis. Estonia has provided three documents: National Security Concept of Estonia 2010; Estonian Defence Industry Policy 2013–2022; and Public Procurement Policy. Latvia has provided one document: The State Defence Concept 2012. Lithuania has provided three documents: Lithuanian Defence Policy; The Military Strategy of the Republic of Lithuania 2016; and National Security Strategy 2012.[29]

National Security Concept of Estonia[30] doesn't mention defence research and innovation, but Defence Industry Policy 2013–2022[31] is largely based on the understanding of the importance of this field. It is related to the Strategy for defence research and development from 2008, which indicates that Estonia has had a strategic vision on defence research and innovation for at least ten years. It is admitted in the Defence Industry Policy 2013–2022 that "[t]he development of the defence industry is closely related to defence-related research and development, as a result of which the fields must be coordinated with each other."[32] The document also specifies the peculiarities of defence industry which require closer cooperation between the government and the private sector, which is determined by such factors "as limited range of users for products, exceptional export regime, exceptional sales environment, higher industrial espionage risk, and heightened security requirements."[33] Estonia's defence industry includes such areas as: "manufacturing of equipment used for defence and security purposes; maintenance and repair of equipment used for defence and security purposes; provision of goods or services of a critical nature during a time of crisis and wartime."[34] The Public Procurement Policy[35] regulates procurement procedures that are beyond the scope of this study.

Latvia's State Defence Concept 2012[36] does not mention defence research and innovation, but it includes an understanding of the importance of modern defence technologies. The document recognises that "new fighting techniques, technology development and application trends must be taken into account while ensuring national defence," and "national defence and security are affected by risks related to rapid technological progress, where the most negative impact may be posed by a combination of high-technology with weapons of mass destruction and electromagnetic weapons."[37] The document also provides that "procurement and logistics projects are synchronised with the development priorities of combat capabilities," and "bearing in mind the discouraging prospects of Latvia's demographic development, more attention must be paid to technology-centric capabilities that do not require significant staff resources."[38] According to the document, military acquisitions are planned in a way as to promote the economy of Latvia. Indirectly, some of the steps outlined in reaching this goal may also include the need for defence research and innovation. For example, "participating in multilateral cooperation projects", "organising joint military procurement with other Baltic states", "promoting the participation of Latvian private enterprises in NATO military industry supply and transit chains", and "promoting the competitiveness of private enterprises and development of technologies, focusing on the involvement of local suppliers in the performance of large-scale military goods procurement contracts."[39] The updated version of the State Defence Concept was adopted in 2016.[40] The document recognises the need to develop the local military industry and use the local scientific base for the development of military capabilities,[41] which demonstrates the growing understanding of the importance of military research and development in Latvia.

None of the documents provided by Lithuania on the EDA website[42] mention issues related to defence research and innovation. To summarise the review of policies and strategies in the area of defence research and innovation in the Baltic states as it is represented in the EDA website, one can use a conclusion by Lisa A. Aronsson that "today, many European allies acknowledge the importance of technology and innovation in defence", however only a few European countries have their own national defence innovation strategies.[43] This is largely related to the Baltic states because only Estonia has a document which has a detailed description of the defence research and innovation, however, this area is subordinate to the defence industry development. The review of policies and strategies gives an idea that defence research and innovation is an underdeveloped area in the Baltic states.

ORGANISATION

Effective defence research and innovation development requires a specific mindset and management approach. For example, the Defence Innovation Initiative of the UK Ministry of Defence among core principles names "an open innovation 'ecosystem' that capitalises on innovative expertise at the MOD and other national security departments, and builds effective, efficient and fertile partnerships with innovators in industry and academia, as well as with key allies and partners."[44] For the various actors of defence research and innovation to be able to cooperate effectively, specific organisational structures are required. The Defence and Security Accelerator[45] that is a part of the Defence Science and Technology Laboratory,[46] which is sponsored by the UK Ministry of Defence, is one of the examples how a strategic vision of the need to develop defence research and innovation translates into organisational structures that facilitate it.

Estonia's Defence Industry Policy 2013–2022[47] outlines the bodies responsible for the implementation of the objectives. According to the document, the supervisory body is the Defence Industry Council, whereas the execution of the policy is the responsibility of four bodies – the Ministry of Defence, the Defence Forces, the Ministry of the Interior, as well as the defence industry.[48] However, the document does not mention specific structures responsible for the development of defence research and innovation as it is in the case of the UK. It may be assumed that such structures are also absent in Latvia and Lithuania because defence research and innovation is not included in policies and strategies that were reviewed within the scope of this study.

Nevertheless, the development of professional associations and clusters in the defence industry may be mentioned as one of the steps taken in the Baltic states to facilitate the growth of the defence industry, which potentially may have implications for the development of defence research and innovation as well. This mindset is present in former Latvia's Prime Minister Māris Kučinskis' government defence priorities: "We will create a national military industrial basis for the needs of maintenance and supply of the National Armed Forces and the National

Guard, using the potential of local national economy and science. We will ensure the involvement of Latvian companies in NATO supply chains and support programmes of the European Union level, thus promoting competitiveness, creation of new and innovative defence products and military technologies."[49]

The Estonian Defence Research Association was established in 2009, but the Estonian Defence Security and Innovation Cluster was established in 2012.[50] The aim of the cluster is "to become the center of competence in research and development and export in the field."[51] The Federation of Security and Defence Industries of Latvia was established in 2013 and involves commercial organisations, leading universities and research institutions.[52] From the strategy of the federation one may conclude that its main focus is resource acquisition because the vision of the organisation is "to increase the volume of transactions in Latvia's security sector to EUR X million and to obtain at least €1 million worth of procurements from EU and NATO projects."[53] Lithuanian Defence and Security Industry Association was established in 2014, and it aims to strengthen the industry, to provide supplies for Lithuanian defence and security capabilities development, and to promote Lithuanian industry and science locally and internationally.[54] This brief overview leads to a conclusion that defence research and innovation in the Baltic states is a result of bottom-up initiatives of the industry which is largely determined by their economic interests. However, the effective development of the field also requires top-down strategic vision and its implementation plan at a governmental level.

FUNDING

Availability of funding is a must for the development of defence research and innovation. EDA provides comparative data on defence in a period from 2005 to 2016[55], which gives insight to defence R&D and R&T (research and technologies) expenditure in the Baltic states (Table 2). As it can be seen from the data, Estonia has had small investments in defence R&D and R&T in the whole period, Latvia had zero expenditure

Table 2. Defence R&D and R&T expenditure.

Source: European Defence Agency. Notes: R&T expenditure – subset of R&D. The Estonian accounting system does not allow distinguishing R&T expenditure from R&D expenditure. "c" – confidential.

	Estonia		Latvia		Lithuania	
Year	R&D	R&T	R&D	R&T	R&D	R&T
2005	€ 0.5 Mln	€ 0.5 Mln	€ 0.2 Mln	€ 0.2 Mln	€ 0.1 Mln	€ 0.1 Mln
2006	€ 1.1 Mln	€ 0.0 Mln	€ 0.4 Mln	c	€ 0.0 Mln	€ 0.0 Mln
2007	€ 1.1 Mln	€ 0.8 Mln	€ 0.3 Mln	c	€ 0.0 Mln	€ 0.0 Mln
2008	€ 1.9 Mln	€ 1.6 Mln	€ 0.2 Mln	c	€ 0.0 Mln	€ 0.0 Mln
2009	€ 0.3 Mln	€ 0.3 Mln	€ 0.2 Mln	c	€ 0.0 Mln	€ 0.0 Mln
2010	€ 0.7 Mln	€ 0.7 Mln	€ 0.0 Mln	c	€ 0.0 Mln	€ 0.0 Mln
2011	€ 0.2 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln
2012	€ 1.1 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln
2013	€ 0.5 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln
2014	€ 1.5 Mln	€ 1.5 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln
2015	€ 1.7 Mln	€ 1.7 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln
2016	€ 1.3 Mln	€ 1.3 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln	€ 0.0 Mln

from 2010 to 2016, and Lithuania had zero expenditure from 2006 to 2016. Estonia's consistent investment in defence research and innovation is present also in the 2018–2021 Development Plan of the Ministry of Defence, which "sets aside funding for research and development, and calls for the doubling of support for Estonia's defense industry sector."[56]

However, if all the Baltic states are viewed together, it may be concluded that defence research and innovation had been almost non-existent in the Baltic states, although this might change. NATO data on defence expenditure from 2011 to 2018[57] includes expenditure on defence R&D in equipment expenditure. Although this data makes it impossible to say what is the exact amount of expenditure on R&D, it provides evidence that expenditure on equipment as a percentage of total defence expenditure tends to increase in the Baltic states since 2014 (Figure 4). It can open up opportunities for the development of defence research and innovation as well.

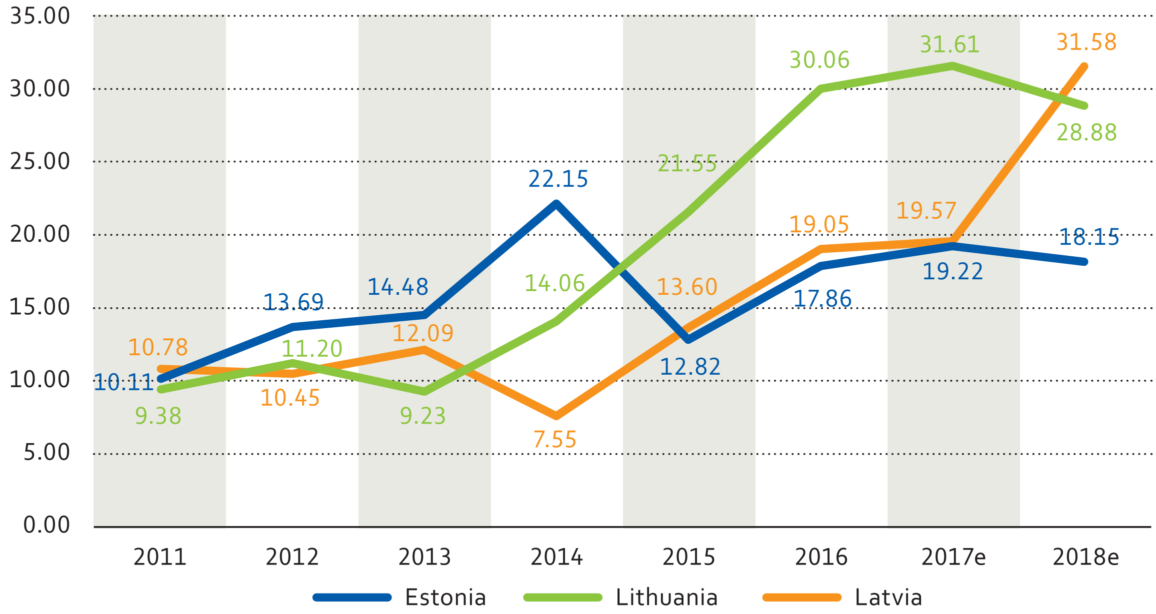

Figure 4. Defence expenditure on equipment (percentage of total defence expenditure).
Source: NATO (2018). Notes: Figures for 2017 and 2018 are estimates.

CONCLUSION

Defence research and innovation is an integral part of the overall R&D development, which is limited in the Baltic states in comparison with economically and technologically more advanced countries. Among the Baltic states, Estonia is the most advanced in R&D, however, in a comparative perspective, all three Baltic states belong to a group of countries with innovation capacity below the average. This forms an unfavourable macro-level context for defence research and development in the Baltic states. Therefore, it is not surprising that defence research and innovation in the Baltic states also is an underdeveloped area.

In the global context, the Baltic states are a part of Europe, which is lagging behind the USA and China in the area of defence research and innovation. Nevertheless, since 2014 at the EU and NATO level significant steps are being taken in terms of the adoption of strategic documents and fund allocation to facilitate the growth of defence research and innovation. This creates favourable external conditions for defence research and innovation in the Baltic states.

For successful development of defence research and innovation, it must be viewed as an ecosystem formed by special policies and strategies, allocation of sufficient funding, specific management culture and organisational structures. Estonia may be regarded as the most advanced among the Baltic states in this regard, because the issues of defence research and innovation have been included at a strategic planning level for at least a ten-year period, and the state budget for defence research and innovation has also been consistently allocated.

For the effective use of opportunities provided by the EU and NATO in the area of defence research and innovation, all three Baltic states must take a strategic and long-term approach at a governmental level, because the possibility to integrate into European and Transatlantic processes is determined by the scientific capacity of the Baltic states, which cannot be developed by the defence industry alone.

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UNMANNED GROUND VEHICLES IN DEVELOPMENT AND PRACTICE: COUNTRY STUDIES

CANADA

Yazan Qasrawi, Abdeslem Boukhtouta and Peter Gizewski

Advances in unmanned ground vehicle (UGV) technology generate considerable attention in the military community. This interest is in part due to the military's recognition of the potential utility of UGVs in saving lives and helping attain objectives in austere and hostile environments. As such, the Canadian Army (CA) considers the implications of UGVs when conceiving and designing their Army of Tomorrow.[1]

This chapter investigates the use of UGVs in future CA land operations. Specifically, it presents a CA perspective of how it's Army of Tomorrow (AoT) capstone operating concept foresees the exploitation of UGVs and their associated technologies. Additionally, it will demonstrate how UGVs and associated technologies can contribute toward the CA's vision of the future as provided in the Future Army's desired outcomes to sustain adaptive dispersed operations (ADO),[2] satisfying the requirements of the Close Engagement (CE) concept.[3] The AoT is a conceptual model of how the CA should operate, including how it is to be configured, equipped, and trained, over the next 20 years. CE is the capstone operating concept for AoT, and is intended to ensure that the CA capability development proceeds in a purposeful and coherent manner.[4] The discussion will also provide a consolidated look at technological trends that may impact the future operational efficiency and effectiveness of the CA. This chapter will discuss the CA's conceptual vision for the future role of UGVs, with an overview of the different taxonomies currently used for classifying them. The limitations and challenges associated with the use of UGVs on operations and an overview of current Canadian UGV capabilities as well as research efforts and disruptive technologies pertaining to the CA's AoT functions will be showcased. The chapter will conclude with an examination of current and anticipated UGV applications and technologies that may impact the CAF's functions.

THE CANADIAN ARMY'S CONCEPTUAL VISION OF THE FUTURE ROLE OF UGVS

Close Engagement (CE), the capstone operating concept for the Canadian Army of Tomorrow, states that the Canadian Armed Forces (CAF) is expected to evolve and adapt within a Future Security Environment (FSE) characterised by hostile and uncertain contexts involving major challenges.[5] The ADO concept requires the CA to operate across larger geographic areas within theatres of operations with a much lower density of forces. It is believed that UGVs will allow the CA to accomplish this[6] and will enable dispersed deployment while enabling rapid re-aggregation when necessary. Particularly, it is anticipated that UGVs will be able to deliver effective sustainment to in-theatre dispersed forces, potentially producing an increase in the standoff distance between the CA and opposing forces.[7]

An analysis of the Future Operating Environment (FOE) identifies factors that will support the use of UGVs. They include:

- The public's reluctance to accept causalities during operations,
- The need to reduce the reaction time for complex or time-sensitive tasks,
- The need to reduce soldiers' cognitive and physical burden,
- The need to work in contested urban environments,
- The need to work in an environment that is dangerous or prohibitive for humans, and
- The need for the CAF to evolve and adapt to the technological challenges and opportunities posed in a rapidly evolving information age.

Canada's Defence Policy *Strong, Secure, Engaged* (SSE), acknowledges that Canada must position itself internationally to take maximum advantage of emerging technologies such as data analytics, deep learning, and autonomous systems.[8] One of the top priorities of new technologies identified for exploitation in SSE is remotely piloted systems. In terms of Army-specific investments, SSE includes modernised logistics vehicles, improved communications, and sustainment equipment.

The CA publication *No Man's Land*, a technical research publication, provides a more detailed perspective on the potential future employment of unmanned systems and a roadmap for their incorporation into future concepts.[9] Canada's *Future Army Vol. 2* states that:

- "Autonomous systems would be worth pursuing if they can replace soldiers in dirty, dull, dangerous or denied tasks,"[10]
- "There is an urgent need for the development of an army roadmap for robotics and unmanned system development that considers both internal lines of development and integration with the other environments within the CAF, allies, and partners."[11]

Beyond this and with regard to external threats, *Future Army Vol. 2* goes on to note that "(t)he future army will require the necessary Ground Based Air Defence (GBAD) or Counter Rocket, Artillery, and Mortar (CRAM) capability to provide its own defence against attack from manned and unmanned platforms as well as munitions at the tactical level."[12] Accordingly, it will require the means to maintain early warning of emerging autonomous technologies and trends to mitigate subsequent impacts on the force.

TAXONOMY OF MILITARY UGVS

In the publication *No Man's Land*, the Canadian Army Land Warfare Centre (CALWC) presents an unmanned systems taxonomy in Figure 1, with UGVs classified into four categories: Manual or Remote Control Systems; Smart or Automated Systems; Mixed Mode Systems (semi-autonomous); and Autonomous Systems.[13] Other classifications are offered in the literature based on levels of autonomy, size, functionality (military, industrial, and commercial and, perhaps in the future, household), endurance, mission type, communications, command, and control (C3) link, etc. For example, Beckman, Collier, and Giesbrecht classified UGVs based on their size and weight: mini (e.g. Dragon Runner[14]); small (e.g. Packbot[15]; Talon[16]); intermediate (e.g. tEODor[17]); and large (e.g. SMSS[18]).[19]

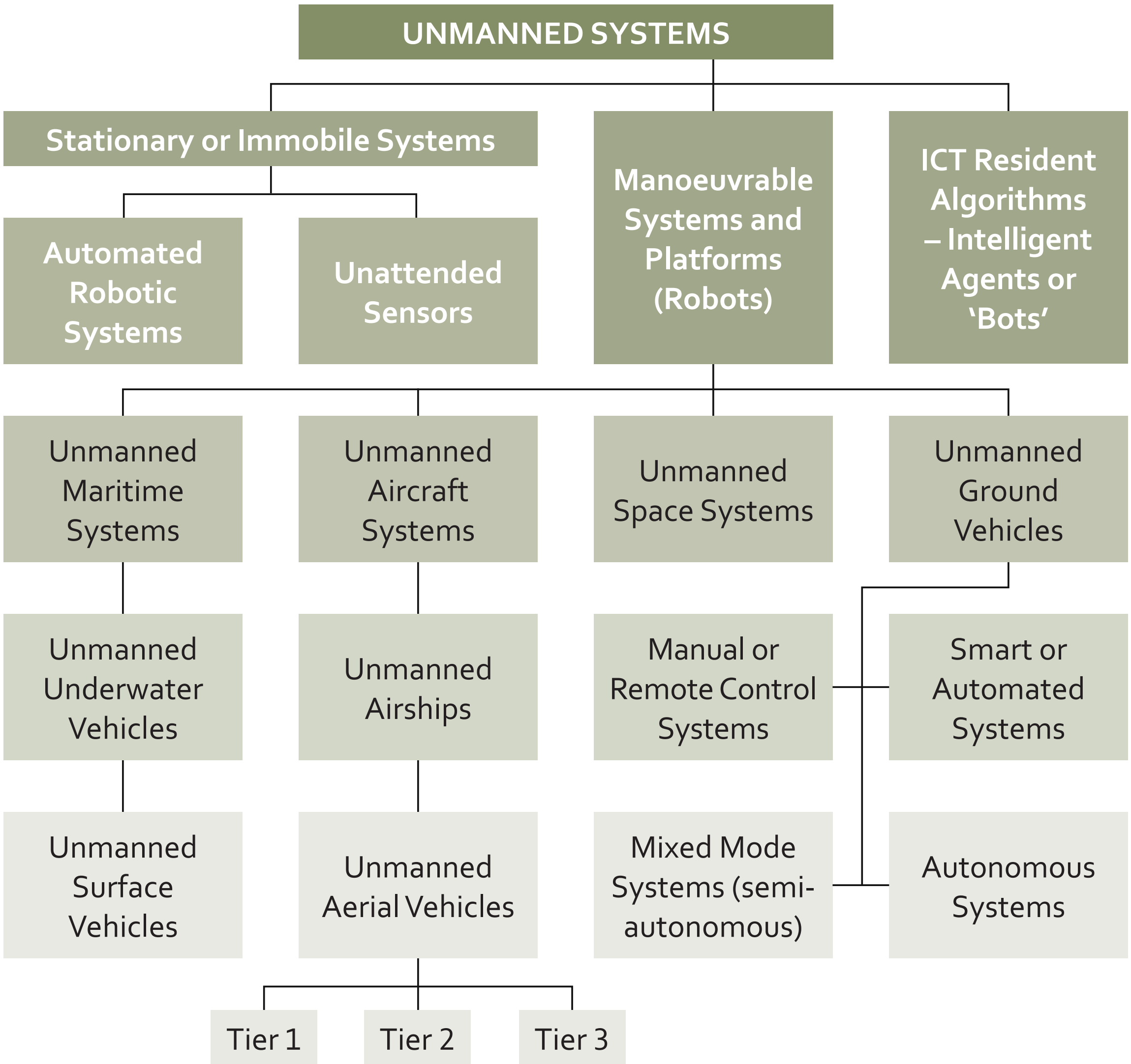

Figure 1. Unmanned Systems Taxonomy used by CALWC

Source: "No Man's Land: Tech considerations for Canada's Future Army," Department of National Defence, Canadian Army Land Warfare Centre, Kingston, Ontario, 2014.

One of the key criteria for classifying UGVs is autonomy. Greater degrees of autonomy allow unmanned systems to operate over longer distances with reduced operator burden while allowing more systems to be controlled by a single human. UGVs can exhibit different levels of autonomy, with some capable of performing their "duties" with limited human intervention, while others require more human direction to achieve their missions (human-controlled or tele-operated UGVs). However, most UGVs require operator intervention at certain stages. The degree of human intervention (and hence, the degree of UGV autonomy) is dependent on the operational environment and mission. For example, a UGV may be able to navigate autonomously in a structured environment such as a warehouse and may rely on tele-operation in an unstructured environment. Tele-operated UGVs are those most widely used today, while semi-autonomous UGVs provide automation for certain aspects of their use such as those that can follow Global Positioning System (GPS) waypoints and avoid obstacles. Fully autonomous ground vehicles can make their own decisions and operate without human intervention for extended time periods. That said, they remain a long-term goal and are a subject of extensive research. Accordingly, in situations in which lives are at stake, tele-operated and semi-autonomous military ground vehicles are likely to represent the most exploited types of UGVs in the short to medium term.

UGV IMPACTS AND EXPECTED BENEFITS ON THE CAF'S OPERATIONS

The missions with the highest potential for UGV employment are replenishment and distribution of critical supplies including medical equipment. This process includes the transportation of supplies for units in the field; shipping and delivery; material handling in warehouses; and convoy protection from automated systems (perhaps in the form of unmanned convoys able to plan their own route and dynamically adapt to changing conditions).[20] Militaries have also employed UGVs for search and rescue, tactical training, surveillance and patrolling, armed attack, and aspects of force protection. UGVs are expected to continue to perform many dangerous jobs, such as demining missions, that would expose humans to risk or prolonged repetition. The ideal situation would be that the technology advances enough for UGVs to be able to undertake these tasks with minimal or no supervision.

Employing UGVs can reduce the risk to personnel and reduce casualties. Additionally, these systems are expected to reduce the soldier's physical load. Other potential benefits of these systems are the long-term cost reductions that may be associated with the training of personnel or with reducing the number of platforms, extending the range of dismounted operations, and enabling resupply in austere, denied, or remote locations that current platforms cannot access.

The expected evolution of UGVs over the next two decades is significant and is focused on reducing the role of humans in directly controlling their autonomous systems. By 2040, greater reliance on fully autonomous ground vehicles for front line re-supply, and automated robot "mules" embedded with dismounted personnel are all envisioned.[21] That said, the degree to which UGVs will be integrated into land operations will be the result of an assessment of potential benefits and risks.

CHALLENGES FACED BY MILITARY UGVS

The technology for fully autonomous UGVs currently remains immature. UGVs rely on machine learning, GPS, radar, and a human interface of some kind to assign tasks to the device. The main challenge lies in increasing their autonomy. It is also necessary to increase the performance capabilities of a team of heterogonous UGVs.

Energy storage and expenditure; communications; coordination with other autonomous devices; and performance under complex conditions are among the additional challenges for UGVs. UGVs require more precise sensing and intelligence as their surroundings become increasingly complex, especially in inhabited areas. To navigate and avoid obstacles in an autonomous mode, UGVs require real-time positional information, pathfinding, and the ability to avoid obstacles, both foreseen and unforeseen. This requires a constant GPS or spatial location signal or self-contained navigation (such as inertial navigation) and sensing system to tell the device where in the physical space it exists.[22] These systems need energy to operate, whether from batteries or liquid fuels.[23] Military UGVs also have to perform in different weather and daylight conditions.

UGVS CURRENTLY OPERATED BY THE CAF

Currently, UGVs are providing an important capability to the CA and they are employed in niche roles such as counter-improvised explosive device (C-IED), clearance. and chemical, biological, radiological, and nuclear (CBRN) detection and defence. tEODor and Mk 2D are two tele-operated UGVs used by the CAF for Explosive Ordnance Disposal (EOD) and C-IED, with approximately fifty units of each of these two systems. The mini wheeled Cobra MkII and the tracked Dragon Runner DR-20 UGVs were acquired by the CAF in 2013 and 2009, respectively, for C-IED and EOD reconnaissance. The CAF also has four Bozena 5 large wheeled remotely controlled UGVs used for clearance of antipersonnel and antitank land mines as well as for IED removal. The Multi-Agent Tactical Sentry (MATS) is a large wheeled UGV (tele-operated from portable control station) that has been developed by Defence Research and Development Canada (DRDC) and has been used by the CAF in CBRN reconnaissance and detection operations for over 12 years. The MATS UGV has also been used by the CAF at CFS Alert during the CAF Joint Arctic Experiment (CAE) in July of 2014. In this experiment (which involved a crashed satellite), MATS used its remote manipulator arm to pick up a simulated satellite fuel tank and deliver a sensor package. Twenty units of iRobot 510, a small tracked UGV, have been acquired by the CAF in 2015 and are currently used by the Canadian Joint Incident Response Unit (CJIRU) for CBRN reconnaissance.

Beyond this, Canada is currently pursuing several additional research and development projects in the area of autonomy. For instance, one such project is dedicated to autonomous platforms in degraded and complex environments and will aim to discover what roles will most feasibly be conducted in the future with autonomous systems. Indeed, both interest and efforts aimed at exploring potential applications is not only evident but accelerating.

POSSIBLE UGV DISRUPTIVE TECHNOLOGIES

Vehicle Convoy and Bulk Supply

The use of heavy trucks in convoys to move large loads of fuel, ammunition, water, and other bulk supplies is standard practice in the CAF. However, casualties incurred during bulk deliveries show that ground convoys are highly vulnerable to attack. Concerns that ground convoys are vulnerable to attack were articulated in the Manley Report that recommended greater reliance on helicopters for logistics as a means of reducing the risk of road casualties.[24] Emerging technologies for ground delivery of bulk supplies could also lessen the risk of casualties by reducing – or possibly eliminating – the need for the involvement of personnel in ground convoys.

The CAF is interested in military programmes involving automation of individual vehicles and convoys. The Defence Advanced Research Projects Agency's (DARPA) "new Ground X-Vehicle Technology (GXV-T) programme aims to break the "more armour" paradigm."[25] The GXV-T program seeks to develop advanced technologies with radically enhanced mobility that can access 95% of terrain.[26] The development of these technologies would also greatly benefit the CAF.

The unmanned ground systems for distribution are autonomous driving systems installed on existing logistics trucks. For logistic convoys, UGVs could be robotic follower elements (i.e., behind manned vehicles). The Convoy Active Safety Technologies (CAST) and Autonomous Mobility Applique System (AMAS) systems include the use of sensors to detect and monitor the environment to navigate large trucks for delivering supplies. Experiments on CAST show that the system is capable of automatically avoiding single obstacles, such as simulated pedestrians, and continuing the assigned route.[27] The AMAS program represents an improvement over the CAST system by addressing the complexity of convoy operations in an urban environment on secondary roads.[28] The TerraMax system was developed to automatically navigate trucks to the desired location. The manufacturer claims that the system reaches its destination on a test course of 11 km in rural terrain, followed by a 97 km simulation in an urban environment, it can be installed on any truck and therefore can be refitted on vehicles already in-service.[29] TerraMax can be used for a single vehicle or for an entire convoy of vehicles, all under the control of a single human operator.

Dismounted Load Carriage

UGVs can alleviate burdens imposed in circumstances judged to involve excessive soldier load while allowing for high levels of agility and dispersion.[30] The Squad Mission Support System (SMSS) is a small six-wheeled UGV providing logistics support for light and early-entry forces operating in asymmetrical and urban battlefields. It is intended to accompany an infantry section on operations and carry some of the load that soldiers typically carry on their person and consequently to extend soldiers' range, reduce their fatigue, and enhance the overall mobility of an infantry section. The SMSS carries a maximum of 680 kg for a maximum distance of 96 km. It can carry packs, water, ammunition, fuel, spare parts, and mission equipment to support the infantry section. Reducing the payload for Canadian soldiers will extend mission range, thereby contributing to Adaptive Dispersed Operations. The SMSS can be configured for Intelligence, Surveillance, and Reconnaissance (ISR) missions as well.[31]

Robotic mules are load carriage platforms that rely on legs rather than wheels, resembling large robot cats or dogs. While such systems currently possess technical limitations, their potential utility is nonetheless compelling – particularly if such limitations can eventually be surmounted. More specifically, the advantage that these legged systems have over wheeled systems is that they can move over terrain that wheeled vehicles cannot, including areas where no roads exist, stairs (indoors if required), and step over rubble rather than rolling over it. This means that legged vehicles could accompany soldiers indoors, in a situation where stairs are the only means of access. Most of these platforms are made in partnership with DARPA's Legged Squad Support System (LS3) project.[32] The Big Dog is a legged autonomous system that walks like an animal and can climb stairs inside buildings. The Big Dog weighs 190 kg, is capable of carrying a 45 kg payload, navigates using LIDAR systems, and has a top speed of 8 km/h, slightly faster than the average walking pace of soldiers. The Wild Cat and Cheetah are other legged autonomous systems that operate in a similar fashion and have speeds of 32 km/h, and 45 km/h respectively but do not carry payloads.[33]

Another potential use for UGVs is in medical evacuations. The Black Knight Transformer is an unmanned hybrid combining characteristics of a helicopter and a truck and is capable of driving at a speed of up to 110 km/h on the ground carrying a payload of 450 kg if equipped to drive, and up to 680 kg if only equipped to fly.[34] Beyond this, it has potential delivery applications when airspace is contested, and areas can only be accessed by road.

UGV APPLICATIONS AND TECHNOLOGIES: IMPACT ON OPERATING FUNCTIONS

Potential employment of unmanned systems in land operations will continue to evolve and UGVs will proliferate within the future operating environment. This section discusses a number of UGV applications and technologies that can be considered to impact CA's operating functions: command, sense, act, shield, and sustain. While not intended to be exhaustive, they are suggestive of future possibilities.

Command. It is possible that self-managing UGV assets, acting as a communication network, will be deployable and function autonomously as a ground-based network relay not dependent on commercial or foreign satellite providers. This will allow the Army to ensure the connectivity of a wider battlespace and consequently directly support the Command function.

Sense. Some of the applications of UGVs that are related to the Sense function could include sending small UGVs into buildings of interest in urban areas for investigation. While inside, they can perform reconnaissance functions, such as confirming the presence of enemies or providing digital floorplans. They can also be used for target acquisition and designation as well as for providing surveillance and counter-sniper or counter-battery support.

Act. There are numerous ethical, moral, and policy implications to Act activities that need to be addressed before arming UGVs is possible. Canada is currently in the process of exploring – along with other nations – the feasibility of a convention committing parties to banning fully autonomous lethal weapon systems.[35] Nevertheless, UGVs can also be used in search and rescue operations to locate personnel in dangerous or difficult situations, such as under enemy fire or during disaster assistance, extract casualties from hazardous environments, and perform medical and casualty evacuations.

Shield. UGVs are already used in C-IED search, clearance, and route opening and their use for this dangerous activity will likely expand as the technology matures. UGVs will continue to be used in demining activities. Another area that can continue to benefit from the use of UGVs is CBRN detection and defence.

Sustain. UGVs will potentially have their greatest impact and utility upon sustainment in land operations. They may be used to resupply geographically distributed soldiers over rough terrain and deliver goods with less protection or infrastructure, resupply troops under fire or over enemy-held territory, and to enable longer-range dismounted operations. The Sustainment uses of UGVs can be extended to materiel handling and warehouse operations. Warehouse robots or unmanned vehicles are used by a number of large commercial enterprises, but these systems are still not widely used within military warehouses. UGVs can potentially be used to operate warehouses, replenishment points, load and unload vehicles, and handle dangerous goods and ammunition.

CONCLUSION

This article explored potential uses of UGVs in support of land operations and possible applications within a future land operations context. The document outlined the CA's UGV vision in published conceptual documents, common schemes for classifying UGVs, likely advantages and disadvantages of the use of UGVs in land operations, summarised the CAF's current UGV inventory and research and development projects, enumerated potential disruptive UGV technologies, and examined how UGVs may potentially impact land operations, by operating function.

UGVs offer a reduced risk in making deliveries and improved endurance by off-loading tasks from humans to machines. Caution should be exercised in measuring in how many tasks, and under what conditions, UGVs will be a suitable replacement for human operators. UGVs offer great potential for simplifying the CA's operations, however, the limits of this technology (e.g. reduced performance in complex urban terrain, compared to simpler rural terrain) should be considered.

UGVs can reduce risk to soldiers, could be used to reduce cost, and increase the effectiveness of the CA. The technology, however, needs further development in the areas of autonomy and fleet coordination before it reaches its full potential and utility. It is anticipated that UGVs will have an impact across the full spectrum of land operations, and it is anticipated that they will have the greatest impact on the "Sustain" function. Delivering goods using UGVs will be increasingly necessary to sustain forces with the required level of agility and dispersion.

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GERMANY

Mirosław Smolarek

Germany has a long tradition of the production and use of UGVs (in German *ein unbemanntes Bodenfahrzeug* or *ein unbemanntes Landfahrzeug*). Already in 1940, during World War II, the German army commissioned Borgward company to design a remotely controlled small vehicle which could be used for delivering high explosives towards targets in order to blow up enemy fortifications, installations, or equipment. The first electric-powered UGV called Gerät 67 (popular name Goliath – SdKfz.302) was 1,5 m long, 0,85 m wide, and 0,56 m high, weighed 370 kg and could move with the maximum speed of up to 10 km/h. It could deliver ca. 80 kg of payload (high explosives) to the distance of ca. 800 m. Goliath was remotely controlled via an electric cable (three wires: two for controlling movement and one for igniting the high explosives).[1] The next development was a cheaper version (SdKfz.303) with a gasoline engine, stronger armour, and longer range (ca. 6–8 km). Moreover, Germans developed much heavier (ca. 300 kg payload) remote controlled version called SdKfz.304.[2] The first pieces of Goliath were tested in combat in 1942 in nearby Sevastopol (then the Soviet Union), as well as in Anzio (1944, Italy), during the Warsaw Uprising (1944, Poland), and during the defence of Wrocław (1945, Poland).[3]

CURRENT USE OF UGVS BY THE GERMAN ARMY

Nowadays the German industry offers a large variety of UGVs, however, the German Army – Bundeswehr, uses them to a rather limited extent. More advanced use can be seen in the case of Unmanned Aerial Vehicles

(UAVs). It is worth mentioning that the Bundeswehr was one of the first armies in the world that introduced a reconnaissance drone in 1969 (Canadair CL-89).

Mine clearing UGVs

Currently, the area of use of the UGVs that the Bundeswehr mainly focusses on are mine clearing solutions. One of UGVs used by German soldiers is tEODor (telerob Explosive Ordnance Disposal and observation robot—*Manipulationsfahrzeug tEODor* in German), manufactured by the Telerob company. The German Army utilizes this robot from 2003 and currently possesses 73 pieces of tEODors.[4] The UGV is used for Explosive Ordnance Disposal (EOD) recce, identification, and removal of improvised explosive devices (IEDs) and unexploded ordinance (UXOs) and can even detonate suspicious items with shots from a recoilless rifle. The machine weights 360 kg, can be operated from the distance of up to 200 m, and moves with the speed of 3 km/h. tEODor can operate on batteries for up to 4 hrs (20 hrs only in camera mode). With the help of the robot, an operator can lift items which weight up to 20 kg with the maximal reach of the manipulator (181 cm), and up to 100 kg during close-in (40 cm). tEODor possesses climbing (45 degree) and fording (30 cm) abilities and can overcome small obstacles (25 cm).[5] tEODors have been intensively used by the German soldiers in Afghanistan.

The next demining unmanned solution used by the German army is Packbot 501. In 2006–2007, the Bundeswehr bought 40 pieces of these robots, manufactured by the USA Irobot company in EOD version.[6] Packbot is a combat-proven (Iraq, Afghanistan) small, lightweight (ca. 24 kg with the manipulator) remotely controlled machine, which can be used by EOD teams for bomb disposal, surveillance and reconnaissance, chemical, biological, radiological, and nuclear (CBRN) / HazMat detection, and mapping. Stuffed with cameras (infra-red included), microphones, and sensors, the device can transmit information directly to an operator's tablet. The special manipulator can lift suspicious objects which weight up to 5 kg by full manipulator extension – 187 cm, or 20 kg in close-in mode.[7] Packbot, similarly to tEODor, proved its functionality and usefulness in the International Security Assistance Force (ISAF) operation in Afghanistan.

Other two largest UGVs operated by the German Army are used for the mine-clearing tasks as well. They are a part of a larger project called "Route Clearance System", which was ordered by the Bundeswehr from the German Rheinmetall AG company. The system consists of four vehicles: a command and operating centre, a detection unit, a demining unit, and a transportation vehicle. The main (manned) element is an armoured transporter (TPz Fuchs KAI) used by a crew as a command and control centre from which the operator can direct other UGVs, collect and evaluate data. Moreover, the transporter is equipped with a very powerful manipulator, that is why TPz Fuchs KAI can be used as an independent reconnoitre and demining vehicle as well. One of the UGVs is equipped with ground-penetrating radar and a metal detector in order to identify mines, IEDs or UXOs. The platform is a small tracked vehicle Wiesel 1, especially adapted to this function. Additionally, the machine is equipped with a special manipulator to which one can attach a variety of sensors, which allow the operator to check hotspots like buildings, bridges, etc. The next robot in the system is a remotely controlled tracked demining vehicle called "Mini MineWolf" (MW 240), which can be fitted with different demining equipment such as a tiller, a flail, a manipulator etc. For the transportation of the UGVs military version of MAN trucks are used.

Picture 1. UGVs used in Route Clearance System in Afghanistan.
Source: Rheinmettall[8]

Picture 2. Small reconnaissance UGV *RABE*.

Source: Bundeswehr/ Sebastian Wilke[10]

Reconnaissance UGV

The newest purchase of the German Army is a small reconnaissance robot called "RABE" ("raven"), the name of which is a German acronym derived from ***R**oboter zur **A**ufklärung, **B**eobachtung und **E**rkundung im Orts- und Häuserkampf* (a robot for reconnaissance, observation, exploration, and for combat in urban areas and buildings). The German army has bought 44 RABE from the USA Endeavor Robotics company (the delivery started in the 1st quarter of 2018), but the Bundeswehr's demand is calculated to be 150 pieces. This lightweight (2,5 kg), small (L 38,1 cmx B 22,9 cm x H 10,2 cm) UGV should be used as "eyes of troops". It is equipped with 4 cameras, which provide a 360° picture, and can operate even in low light conditions. RABE can transmit real-time pictures at a distance of 300 m. This very robust robot could be thrown into a building through a window, a hole, etc., or dropped from as high as 5 m. Its gradeability reaches 35° and its climbing ability is up to 18 cm. The UGV will be used by the army and air force units.[9]

PERSPECTIVES

The German government and the armed forces are very cautious about the use of robots in military operations, especially as there are a lot of political and ethical disputes about utilising the so-called combat robots (LAWS- lethal autonomous weapons systems), both terrestrial and airborne. The German government and armed forces understand the role of UGVs in the modern military environment, however, they declare they are not going to acquire "combat robots", at the same time being aware that the army has to be prepared to fight against such new enemy.[11]

Regarding the introduction of the UGVs to Bundeswehr's arsenal, two periods can be observed. The first period lasted from the beginning of this century to 2013/2014 and during this time the German army showed big interest in unmanned ground vehicles. During the second period, which is still taking place, one can observe a decrease of attentiveness to such projects. This situation is probably due to the Bundeswehr's previous involvement in the ISAF mission in Afghanistan and the withdrawal of significant Bundeswehr forces after its end in 2014. Moreover, there is another factor that might influence the attitude towards the money spending on land-based military equipment, namely the annexation of Crimea by Russia. These issues probably have changed the perspective of the German decision makers on defence matters form an expeditionary attitude to NATO Article 5 operations. It seems that the German army has concentrated on the development of manned combat weaponry for future land battles (new IFV PUMA, modernization of MBT Leopard 2 to version A7) and protection of own forces (development of anti-aircraft, artillery, and surveillance systems).

In the first period mentioned above, the Bundeswehr was interested in the implementation of the UGVs especially for the mine clearing, ground reconnaissance, surveillance, Medevac, logistics, and transportation. As was mentioned above, some mine clearing robots have been introduced to the German land forces during that time. Moreover, the Bundeswehr was interested in UGV-related research. Even in 2006, the German Armed Forces organized a competition called ELROB—European Land-Robot Trial (Military edition) for companies, design offices, and scientific research institutions involved in the development of the UGVs, with the idea to adopt the best solutions for military purposes. During ELROB 2008, eleven sophisticated German UGV projects were presented,[12] which demonstrated the potential of the German defence industry, as well as that of civilian research and technology institutions. Based on the experience from ELROB, Bundeswehr was interested in the development of UGVs concepts for surveillance, protection, observation, transport, etc. Some so-called demonstrators like Gecko TRS, Wiesel-2 Digital, ROBO-FUCHS, Foxbot, etc., have been taken into consideration for further development. Additionally, reports prepared for German Armed Forces or German Parliament underlined the role of UGVs on the modern battlefield, however, due to ethical and political considerations, the use of combat (armed) UGVs has been rejected. Nonetheless, the change of the attitude towards UGVs after 2013 can be observed. However, one must admit that the Bundeswehr did not completely lose interest in UGVs as it still sponsors the development of some solutions, such as a demonstrator called TULF (*Technologieträger unbemanntes Landfahrzeug* – demonstrator for unmanned ground vehicle), which is under the development of the German academia and companies (e.g. Universität der Bundeswehr, Universität Koblenz-Landau, Diehl Defence, Rheinmetall Landsysteme, et.al.). Furthermore, interestingly, German industry as well as research and design offices have quite good experience in building UGVs (vide mentioned ELROB competitions) and have some sophisticated solutions „in stock". In 2018, during the EUROSATORY arms exhibition, the German company Rheinmetall AG presented a rather mature modular UGV demonstrator called *Mission Master*, which can be used as a platform for multiple applications. The company offers its product in a cargo version, for surveillance or force protection (a model armed with weapons). Other areas of application of the *Mission Master* could be CBRN detection, Medevac, or as a mobile communication relay.

Nonetheless, it seems that currently in the area of unmanned vehicles the German decision-makers responsible for Armed Forces focus more on acquiring aerial vehicles which will be used not only by the air force but for the land forces and the navy as well, and they are not going to arm the German army with very sophisticated (and expensive) UGVs in nearest future. Nowadays, the German land forces rely on the use of small UAVs for reconnaissance (Aladin, Luna, Mikado, KZO), although it is expected that the army units will be equipped with small unmanned helicopters.[13]

CONCLUSION

The analysis of Bundeswehr's publicly available documents and press releases shows that currently the German government and military leadership is not going to invest too much in UGVs technology. It looks that in the matters of unmanned vehicles, in a short-term perspective, German Armed Forces are rather "UAVs-oriented". One can find proof of this statement in „7. Report of the Federal Ministry of Defence on Armament Affairs" (*7. Bericht des Bundesministeriums der Verteidigung zu Rüstungsangelegenheiten*) published in March 2018. The report mentions 22 main projects important for German Armed Forces, three of them are related to obtaining UAVs (PEGASUS -MQ-4C TRITON; MALE HERON TP and development of EURODROHNE), however, there is no mention of a UGV programme.[14] Strategically, the German government wants to focus on developing cyber defence and space surveillance capabilities, on the modernisation of the existing weaponry, the introduction of new heavy weaponry for the air force, land, and navy, and on obtaining new MALE UAVs. It is obvious that these projects are very expensive and the army budget is quite restricted (planned 1,31% GDP in 2019). It is worth mentioning the big divergence between Bundeswehr's budget proposals offered by the German Ministry of Finance and the expectations of the Ministry of Defence. In May 2018, the Defence Minister Ursula von der Leyen submitted an official protest against the proposed budget.[15] Definitely, the budget shortfalls are one of the main causes as to why currently the Bundeswehr is not oriented towards purchasing a large number of new UGVs. The case of purchasing the small UGV RABE looks like the exception that proves the rule. Probably, the Bundeswehr will still support some research in this area and will occasionally buy a small amount of various UGVs, and this decision will depend on the existing will to buy some pieces for evaluation and experimentation, however, it now appears that the UGVs will have to wait for their “big day” when they will be lavishly introduced into the Bundeswehr in order to directly support or protect German soldiers, but not replace them in combat, and German industry seems to be ready for this day.

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FRANCE

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A brand new tool corresponds to a new way of thinking about the work. Such an aphorism can also apply to the revolution that robotics systems are bringing to the organisation and manoeuvres on tomorrow's battlefields. This article aims to briefly outline them, showing the opportunities that military robotics already offers in engagements in different existing theatres, while also emphasising the revolution in the art of warfare that the development of autonomy in these systems brings and its effect on the role of combatants. It will also lay out France's position in this area, relying on the report published by the Research Centre of the Saint-Cyr Military Academy, the CREC Saint-Cyr, in December 2018, and the contributions of its different authors.[1]

THE ADVANTAGES OF ROBOTICS

Robotics systems are already new tactical pieces, even pieces for manoeuvres, which military commanders will henceforth use in planning their operations, then rely upon to facilitate their advancement by permitting new effects on the enemy, terrain, occupying space and the rhythm of action. They will allow monitoring of the battlefield through the deployment of remote effectors and sensors that permit monitoring different dimensions and areas of the battlefield: land, air, sea, and electromagnetic. They will progressively displace combatants to the rear of contact zones to distance them from dangerous areas and reduce risks, or permitting engagement with a maximum of available means, thus also significantly diminishing the vulnerability of combatants.

Military robotics systems, for the sake of argument, are idealised here without technological or energy constraints and capable of continuously deploying remote sensors and effectors in the battlefield. Such a deployment, other than enlarging the area of operations of a unit, will allow to reduce the unit's reaction time, either to make a decision once information is received or by the utilisation of the deployed effectors, and denying the enemy the possibility of gaining the initiative by surprise.

In addition, the machine reacts faster and with more precision than a person. In effect, if a person takes several seconds to react to a stimulus, a machine does it an automatic manner in several milliseconds, without its action even being visible to humans, allowing for optimal protection for a unit in the case of an enemy attack. The systems also permit the analysis of conditions to allow more precision in the effect to be obtained such as eliminating or compensating for the effects of movement, weather conditions such as wind or fog, visibility conditions (darkness, night), etc.

An inescapable and progressive evolution towards autonomy

Today, in the context of the rapid evolution of technologies of automation and autonomy, the aptitude of drone and robotic systems is developing and will rapidly surpass the limits of remotely-operated systems in service. The automation of tedious, dangerous, and repetitive military tasks which no longer require the attention of a specialist operator are technologically feasible today.[2]

The gradual introduction of functions presenting a high degree of automation within the systems will eventually lead to robots, or systems of robots, in specific cases set out by military commanders, having the possibility of carrying out the task assigned to them without human intervention, as well as being able to adapt their behaviour to evolutions of the situation on the ground. The enlargement of the capabilities of automated systems, which are today restricted to very specialised tasks, opens up the prospects of their use across the spectrum of military actions. This technological evolution is coming during a period when the French Army anticipates that future engagements will be: "the evolution of threats will lead to a thorough modification of land and air operations in the coming decades. The evolution underway will naturally lead to the end of 'operational comfort' (…) numerical advantage will find a new importance."[3]

Army objectives

As major general Charles Beaudouin points out, fully focused on this objective, the Army, one of the leading armies in Europe, will inevitably turn towards the utilisation of robotic systems to hold onto its place and to maintain a development pace that guarantees its interoperability and place amongst its allies, as well as to avoid the risk of a capabilities gap emerging with an adversary that will use all the opportunities offered by progress and innovation. Despite being a comprehensive model, the current organisation of the Army will be a restriction in the event of major engagements: "The scale of forces and their support remains at a historically low level, both in terms of men and materials. The margin of manoeuvre and capabilities for redeployment are severely limited. (…). The insufficiency of the available critical mass, despite the increase in the strength of the reserve, limits the capacity to react and the military freedom of action in the case of an escalating crisis or multiple attacks on our interests and national territory."[4] The Army's need for automated land and air systems is a response to the problem posed by the evolution of engagements by multiplying operating efficacy. [5]

A review of historical developments

Before going further in our reflection on military uses of UGVs, a historical review reveals that the first military robots were put into service in the French Army in 1915. French engineers Aubriot and Gabet developed an electric tracked platform capable of transporting 200 kg of explosives towards barbed wire entanglements. UAVs share the same origins, as in 1916 the British developed a target aircraft, the Aerial Target, which was remotely piloted by radio. A first French demonstration model followed in 1917 produced in small batches, these little-known robots were nevertheless authentic innovations, 25 years before the famous German *Goliath*,[6] which was still inspired by the work of Frenchman Adolphe Kégresse. Weighing at around 400 kg, of which 60 to 100 kg were explosive charges, a total of 7,564 of these vehicles were produced.

The 1990s were crucial years for the introduction of military robots on a large scale, with UGVs being used by mine clearing teams against what can be qualified as the poor man's artillery of the modern day: Improvised Explosive Devices. For the French Army, the PAMIR operation in Afghanistan definitively installed the use of pre-existing drones (SDTI Sperwer[7] of SAFRAN Electronics & Defense and DRAC[8] of THALES) and led to the introduction of new engineering mini-robots and drones (MINIROGEN and DROGEN of ECA), which were urgently deployed in operations by units dealing with improvised explosive devices. More recently, other robotics systems were deployed in operations, such as those on national territory. One can cite the use of Black Hornet nano-drones to conduct reconnaissance of sites and track persons of interest, as well as mini-UGVs NERVA of NEXTER Robotics.

The use of robotics systems in future wars

As a multiplier of operational efficiency, these systems can be employed in an overall plan along three major vectors in future engagements. We can find:

1. Robotic systems conducting surveillance and observation of the battle zone. Having a certain autonomy while remaining subordinate to military command, these systems will be active on a continuous basis, necessitating regular replacement to ensure 24/7 operation in all conditions for the missions which have been assigned to them. These systems will be managed on an operational level by units charged with their deployment to protect infrastructure, borders, or the interior space of terrain occupied by operational units.

2. Robots integrated in operational units: these robots will be under the responsibility of tactical units accompanying soldiers as part of their military activities. They shall be distributed among units, which will have the responsibility for their deployment and use, at the level of company level combat units depending upon the type of robots. They will serve to give an operational advantage over the enemy as well as to reduce the risk and danger posed to combatants from their exposure. Principally such robots will be used in intelligence missions to “scout” or to conduct “reconnaissance”, security missions such as “controlling the area”, and also “support” missions by using their firepower and movement capabilities.
3. Robots used in specialised formations or detached at the brigade level to support manoeuvres, upon request or need. These specialised formations bring together jobs requiring technical skills and operational particularities that only a dedicated formation can provide in certain units. These jobs require notable knowledge of joint services procedures in terms of electronic warfare, logistics and concentration of efforts. Robots could become an absolutely indispensable tool, a partner in military operations for the soldiers who use them. Also, as with tanks in the Second World War, robots may be used *en masse* to achieve a specific objective or to concentrate their destructive capabilities on a particular ground sector. Robotic systems will be used particularly in swarms or in first waves of offensives, or to cover a particular area.

HOW UGVS WILL INFLUENCE THE CAPABILITIES AND TACTICS OF SMALL INFANTRY UNITS

The range of possibilities with military robots is immense and will very likely be one of the major changes in the art of warfare in the future. Without aiming to be exhaustive, we will seek to provide several examples here regarding the possible future evolutions in combat techniques.

The gradual appearance of partner robots

Infantry units employing robots will at first delegate them certain subordinate tasks that are tedious or difficult for soldiers to accomplish over the long term or during moments of intense combat: these will first of all be the automatic detection of intrusions in which pre-treatment of images and captured data will be gradually introduced before they are sent to the unit, where the unit commander will distribute the information to different intervention groups. They will also be given simple functions like parking a vehicle automatically in the case of a collision or disembarkation, or transporting heavy loads, etc.

At first, they will be guided from the rear using tools such as a "tactile tactical table". Later a phase will come when the infantry gradually assigns them missions while maintaining the possibility of retaking control of their operations. These will be missions like surveillance of an area, patrolling, clearing mines from an area, resupply, guarding a flank, etc.

As a tactical piece, over time robots will prove to be a new partner for armies that aim to avoid friendly and collateral losses, which also offers them a return to their roots in terms of manoeuvrability, made possible by the new capabilities they offer soldiers.

24-hour coverage and surveillance

Twenty-four-hour occupation of airspace permits continuous coverage and the ability to remotely deploy effectors in an area enabling maximum reactivity and a reduction of the OODA[9] cycle. This permits reacting to a threat as soon as it is detected and by immediate detection, denying the enemy the opportunity to deploy its device. As a consequence, combat zones in the future will involve three main functional areas:

- Continuous surveillance: intelligence can no longer do without drones, either at the operations level (as is currently the case in Mali with the use of Reaper drones by the French Army) as well as at the tactical level when threats are identified, such as with certain search missions by special forces. France, which has surveillance satellites, is equipping itself with surveillance drones at the operational level (at altitudes of around 20 km like the Stratobus programme of the firm THALES), but also for the monitoring of certain military infrastructure (bases, sensitive areas) or dynamically over certain sectors of terrain as part of military operations.

- In addition to the function of surveillance, **target selection** will permit transmission of the precise coordinates (geolocation) of all suspicious elements or potential targets in order to be validated by military authorities.
- **Infiltration of areas** by medium-sized or even miniature drones provide the capacity of direct observation, as well as the capability to harass and threaten those who use them. This will particularly be the case in homogeneous spaces such as air and maritime environments.

Within these spaces we will find packs of robots with collective intelligence that allows them to move together in a coherent manner: **swarming formations** on either the surface or in the air. They will allow for saturating a given space to achieve a specific objective, ranging from intelligence gathering to saturating with fire. Copying the formations used in manoeuvres by aircraft, naval vessels, and tanks, pack robots will work together to achieve better progression while still respecting the principles of optimal protection.

New intelligence capabilities

In the area of manoeuvres, robots can provide information to their section chief on the position of enemies, that would also permit it to carry out an appropriate manoeuvre to drive off or eliminate the enemy. This latest innovation could be used to:

- Updating standard cartographical data on theatres of operations, with overflights of UAVs and reconnaissance by UGV robots to update the information on ground elevation to determine possible firing lines and ground damage assessments, such as streets and roads blocked, buildings destroyed, groves, etc.;

- Scouting a route: robots can scout a route well ahead of the first manned armoured vehicle. Collecting information from the video feed to make comparisons with previous battle data of the area to determine whether it is overrun, and identifying possibly dangerous areas for IEDs;
- Reconnaissance of advantageous defensive positions where linked UAVs and UGVs permit determining one or more lines of defence, as well as alternative positions;
- Reconnaissance of advantageous offensive positions such as assault bases, support, and covering positions;
- Reconnaissance of alternative itineraries;
- Following the enemy more closely to screen it.

Conduct manoeuvres

According to captain Pierre-Henri Marconnet, instructor at the Tactics and Techniques Training Division of the Saint-Cyr Military Academy, the new tactical pieces that are military robots can offer military commanders new manoeuvring capabilities and new tactical options.

- UGVs can carry out Light Observation Patrols to verify that there are no gaps in forces, taking incomplete areas into account. They can be placed to conduct surveillance on key points of the terrain far from the unit.
- The mission of flank-guard is often mobile and orientated towards intelligence and protection. One can imagine the mission of flank-guard being given to UAV/UGV tandems to detect enemies approaching the perimeter of forces.
- At checkpoints, UGVs could be exposed to danger in place of combatants, such as passing mirrors/cameras under vehicles being inspected and stopping vehicles trying to force their way through the checkpoint using onboard weapons. For suspicious vehicles, they could have remotely manipulated arms to open doors and trunks to keep specialists at a safer distance.

- They could also play a leading role in diversionary manoeuvres using sound effects and smoke screens. They could present a false attack more realistically while avoiding using a portion of the forces in such a decoy manoeuvre.

New offensive capabilities

Here are several examples of what robotic systems can contribute in terms of offensive operations:

- The deployment of aerial artillery closer to the contact: robots carrying lethal charges, which can be triggered remotely, will progressively enter into air operations. Operational units will also have the ability to launch robots at holding altitudes to deploy a charge which can be activated closer to the threat.
- As for the infantry and artillery weapons, in the medium term an evolution of **ground mortars into aerial tactical mortars** (or missiles of opportunity) and the appearance of robotic anti-artillery systems will pose the question of the distribution of these robots in units, especially in combat units. In addition, surveillance UGVs and AUVs will be coupled with traditional heavy artillery for target acquisition, permitting firing at even further distances.
- **Robot screens:** the Russians made a historic first at Latakia, Syria in December 2015, by using armoured and armed UGVs in advance of units to advance and neutralise enemy lines and absorb the first shock of combat.[10] In the same spirit, in the future compact formations of land and air drones will attempt to pierce or pin down enemy lines, as tanks did in the Second World War with air support, revolutionising the art of breakthrough after cavalry and armoured vehicles. After breaking through or neutralising the enemy, a phase of exploiting the situation will follow, which will be coordinated by humans but realised jointly by soldiers and robots.
- **Better targeted offensive capabilities** using robotic systems of low lethality and extreme precision such as the Snibot® robot,

Graduated Surgical Response Neutralisation Drone from SD4E,[11] which integrates an "Exclusion of Vital Zones" algorithm when firing weapons.

Defensive capabilities

- Specialised aerial robotic units will be created to carry out particular functions or effects on the battlefield. Depending on the effector the robot is carrying, it could carry out localised jamming, or use a targeted electromagnetic impulse against enemy equipment to neutralise it, or even try to hack into it. Note, for example, the 2017 incident when 4,000 NATO soldiers were the victim of a massive Russian cyberattack that used specialised drones and portable antennas to gain access to their personal mobile phones.[12]
- Deployment of specialised systems to **counter robotic threats,** neutralising enemy surveillance drones, or interfacing with missiles or charges fired and the forces to be protected. If military robots provide new ways of waging war, the enemy will also strive to use them to their advantage, as demonstrated by the use of drones by Islamic State. It is thus necessary to be able to counter enemy threats using counter-robot measures which can take the form of drones designed to hunt and kill enemy drones which are ultra-reactive, principally in the third dimension.

Support and logistics

A new tool at the service of man, robotics systems, will accompany human actions in the sphere of mobility.

- UGVs can support infantry advances, aiding the rhythm of manoeuvres and providing dynamism to movements. They can provide rhythm to long and tedious marches, but can also aid the launch of an assault by leaving a position to lead combat groups into action.

- UGVs can carry munitions, batteries, rations, water, as well as miscellaneous supplies for combat units. This can help avoid exposing personnel during resupply.
- In addition, UGVs can serve as mules to lighten the load carried by soldiers, who can thus conserve their strength and capacity to fight for longer.
- **The movement of convoys could be delegated to UGVs.** This could be done in particular for movements of convoys along major routes, as well as for resupplying troops closer to combat zones. In the case of convoys, a human escort will be absolutely necessary to ensure protection of the platforms and to intervene, if necessary. However, for resupply closer to danger, it will be preferable to risk the platforms alone rather than exposing the soldiers accompanying them.

Use in urban areas

Colonel Pierre Santoni, former commanding officer of the Training Centre for Operations in Urban Areas – 94th Infantry Regiment at Sissonne, Director of Studies and the Chief of Staff Academy, argues that today, cities and industrial areas have become a place of refuge for asymmetrical enemies to hide and resist, which poses serious difficulties for conventional militaries that rely upon firepower and manoeuvrability. If the battle is taken to such a setting, it enters a world of concrete and steel that is increasingly difficult and costly, in terms of human lives, combat and engineering equipment, and munitions. The battlefield is a place of constant threat from precision weapons, traps and drones. And civilians can easily spot units and provide real-time information about their actions.

In this very hostile, dangerous, and unstructured environment, coupled UGV-UAV robots could be partners to support advances by solders, or to attack. One can imagine robots serving as "guard dogs" or "pointing dogs", robots to breach into basements, metro tunnels, parking garages, underground buildings, to absorb the fire instead of the units following them. Robot lures that are engaged will immediately be followed by *breaching robots*, which are then followed by assault units containing human soldiers. Robots will thus become capable of engaging autonomously in situations too chaotic for humans.

THE MAIN CHALLENGES FRENCH ARMED FORCES WILL FACE INTRODUCING UGV IN COMBAT FUNCTIONS

Organisation of units

As new equipment will be integrated into assembled units, robots will create new organisational constraints.

- At the level of operational units, the use of robots can be handled by formed units, or reserved for robotic combat groups to support other combat groups. The creation of robotic combat groups seems particularly pertinent for robotic systems that require expertise in their operation and a high level of concentration to pilot them, which necessitates putting the operators working to support other units into a second layer.
- For specialised robotics systems, it is likewise desirable to consider the creation of robotic regiments or companies in charge of these specific materials: for example, a company of armed shock robots that could be deployed along the entire front and which is put under the command of the brigade or division. Joint services tactical guidelines should regulate their attribution to units and their use.
- The basic make-up of a classic French infantry company is 3 combat platoons, each of which is made up of 4 combat groups, plus a support section. If it isn't desirable to modify its structure in any way, on the contrary one can consider enriching it. In this regard, one could consider adding a robotic support group to the support section, which would be charged with deploying robots depending on the needs of the manoeuvre, and would also be responsible for their maintenance during combat (replacing batteries, changing effectors). The robotic support group would be

put under the command of the unit commander, and, depending on the disposition of forces on wide open terrain, could also be put under the command of a combat section. One is thus moving towards distributing assault robots to units, rather than creating autonomous robotic entities or specialised regiments.

The control of robots

The piloting of robots for an initial period, then the emergence of autonomous functions, raises the question of control and supervision of robots by the operators within units. Piloting robotic systems requires a level of concentration over the controls that is very difficult to reconcile with the exigencies of close-quarter combat where infantry soldiers, who are under intense stress with a sentiment of overarching insecurity, are concentrating primarily on their weapon, visual and aural environment, the orders they received or should give, as well as the position of their comrades. It is thus desirable to position operators in a second echelon, slightly behind the area of contact, so they can pilot or control the machines.

During a manoeuvre, it seems absolutely necessary that a military robot could be taken over by a unit to which it wasn't originally assigned. Take for example an urban setting where a combat group enters into contact. It should be able to request taking over a piece of robotic equipment if it is better positioned to operate it. This requires a handover capability between units. The transfer of control between several operators, or between commanders, in other words a sharing of authority, should be integrated into the concept of command structures by their engineer designers in cooperation with military authorities.

Doctrine should specify the place and function of the operator within the group. In terms of responsibility, should robots be under the command of section commanders, non-commissioned officers of group commanders? And who will have the responsibility to collect and analyse videos from robots?

Multi-robot formations, with each having different functionalities and specialisations, will be coordinated at the level of military action coordination at the level of the Joint Services Tactical Sub-Group.

Their transport

Means of transport for each robotic system is needed. If current military equipment does not include space to transport robots, they need to be transported, ensuring a maintenance base for them is properly equipped and supplied. This constraint can become an important impediment to the deployment of such systems. It seems to us that at the very least supplementary means of transport need to be given to the company echelon for systems of a certain size, as well as storage boxes or space in certain existing vehicles for smaller robots, or even launch platforms for UAVs on their superstructures.

The advantages of extreme precision[13]

Extreme precision when engaging lethal forces responds not only to the operational needs of the forces, but also the ethical and legal framework that governs the use of arms. Conventional warfare is no longer applicable in the engagements where France and its European allies are currently engaged. Fanatical and religious terrorists have developed a confrontation where all the world should die as their objective: hostages become bait to attract us. In one theatre of operations (Mosul), the civilian population is being used as a human shield to slow down military operations, forcing them to use steamroller tactics that are costly in terms of destruction.

Technology offers superior precision to humans, who are subject to sensorial and psychological effects that do not allow full mobilisation of their capabilities in conflict situations. In a combat situation, the stress of the risks at play for soldiers considerably reduces their cognitive and physical capabilities, jeopardising their effectiveness at the most crucial moment when they must aim and fire their weapon, and remain in control of their firing. However, a drone is guided by an operator who is free from the direct stress of enemy fire and who will be much more operational during the critical phase, offering a real capacity for surgical intervention.

Autonomy and Artificial Intelligence

Sent as close as possible to the military action, omnipresent or deployable robotic systems nevertheless remain dependent upon an operator who retains responsibility for their use, and for their configuration. Any capacity to discern is useless for the machine, it carries out what it was programmed to do. Consequently, the operator always remains engaged.

Nevertheless, with the development of artificial intelligence, robots will progressively acquire capacities to analyse the situation, ultimately allowing it to handle the unexpected, which is moving towards autonomy, although it must remain under supervision. This is where military commanders, naturally interested in delegating certain tasks or missions to these machines, must intervene to always control them and give sense to the military action. The less constrained one is by the piloting and controlling of the machine, the freer one will be in their actions, as long as control can be maintained. In the coming decades, we will thus witness a gradual increase in the autonomous capabilities of the systems, towards an autonomy under control, or more precisely a semi-autonomy, in the sense that the military operator must always ensure:

- Setting restrictions on the capabilities of the machine: for example, to set the limits on the space in which the systems can move;
- Conserving the capability to directly access the machine to regain control over its actions or to deactivate it;
- Regularly receive reports from the machine about its status and its mission objectives.

Accordingly, the superior calculation capabilities and reactivity of Artificial Intelligence compared to humans offers opportunities with the automation of military robotic systems. The difficulty of modelling land environments means that it will need to be supervised in its learning and traceability.

SALSA OR SALA

The position of the French Army is explained by Major General Charles Beaudouin, deputy chief of "plans programs", Army Chief of Staff, who reiterated that the use of Autonomous Lethal Arms Systems (SALA) is a red line the French Army won't cross. On the other hand, the French Chief of Staff has fixed the objective to develop autonomous non-lethal robots and drones by 2030, which will be real team members that soldiers can rely upon in an extremely wide range of missions, such as scouting a route or logistical convoys. By this time the French Army must also master the capability to kill autonomous enemy robots, which will certainly be lethal[14].

The author of this article would like to state, however, that the fundamental question of concern when speaking about the lethality of military robots is autonomy in the decision to fire. However, it seems inescapable to him that in the coming decades lethal weapons systems will gain some form of supervised autonomy in decisions to fire. This is due to the simple fact that it offers the following advantages in terms of defence:

- They are faster in terms of reaction times and threat management than humans;
- They can be used against saturation attacks;
- They can be operated on a 24-hour basis with great consistency whereas humans suffer from fatigue and lapses of attention.

It remains fundamental, however, that military commanders that use them retain mastery in their usage and control over their use. Their usage should thus be supervised, which qualifies them as Semi-Autonomous Lethal Arms Systems (SALSA) and not Autonomous Lethal Arms Systems (SALA). These systems should not be able to pass into "semi-autonomous fire" mode except upon the decision of a human operator, that is to say a military decision-maker trained in these questions. This person will make such decisions based upon their knowledge of the threat, the operating environment and rules of engagement, as well as the tactical environment. This decision-maker thus engages their responsibility. This decision-maker will set the conditions for activation and the constraints to be respected by these systems, including times and areas where they may be activated. This person should also be able to deactivate "semi-autonomous fire" mode at any moment, which implies continuous contact with the machine, which once again removes these systems from the category of being fully autonomous.

Finally, it should be noted that the certain spaces seem more suitable for their operations: air, sea, underwater, in deserts or underground. On the contrary, urban environments do not seem appropriate, because it is extremely difficult for humans to discriminate and characterise the behaviour of potential targets in such dense and heterogenous environments, with the risk of uncontrolled situations being too high.[15]

Opportunities for the French Army

The French Army's SCORPION programme aims to ensure the modernisation of the Joint Services Tactical Groups (GTIAs in French), the replacement of certain equipment and development of new platforms, as well as a unified combat information system.

The formidable transformation of capabilities that this programme represents is the ideal opportunity to permit the French Army to develop its own robotics capability in line with how it views the future of land combat. In particular, this capability will allow to generate critical mass effects: "the robotisation and automation of certain tasks (surveillance, force protection, threat detection, logistical flows) aims to accelerate the operational rhythm and augment impact."[16] A high-tech army, the French Army will resolutely turn towards robotisation with this programme, that it will develop in particular through its Land Battle Lab, which is a direct result of its needs for rapid technical and operational innovations.

In the Land Battle Lab, the first project concerns a "robotic land scout" and to experiment with operational uses to develop different automated modular land platforms designed to support front-line battle groups. This will also aid in the determining of needs for future standards in land robots up to 2030.

WHAT SHOULD BE DONE IN THE FIELD OF UGV-RELATED RESEARCH AND DEVELOPMENT

The first stage: autonomy in movement[17]

In light of what was said above, and to reduce the cognitive charge of operators of robots, the first stage naturally seeks autonomy for robotics systems in terms of mobility. It appears in effect desirable that robots can take over responsibility for a portion of their movements. Beyond the objective of relieving the operator of tasks, it is also a question of improving the performance in terms of movement and limiting risk: removing the operator from control of movement means less information that pilots are used to receiving (typically physical sensorial feedback allowing the pilot to "feel" the forces being put on the vehicle, allowing for the adaption of speed and direction commands). The introduction of automation and local security mechanisms will allow for the compensation of a part of this removal of the pilot. In land environments, one of the major challenges for autonomous movement by UGVs in an open and unstructured area is the satisfactory handling of natural obstacles.

Evolution towards collaboration

Cooperation among robots and coordination of UAVs and UGVs is an indispensable stage in the further evolution of robotics. The interconnection of robotic systems provides a scaling effect and is the early stage of a collective intelligence that will drastically improve the capacity of our forces to react and the precision of their actions. It is therefore necessary to think "collaboratively", particularly in the control of systems, so they are not dedicated to one sole operator, but that they may be used by units which have the greatest need for them at the moment during manoeuvres.

Simulate then test

The robotics revolution should be accompanied. To do this, simulation is an excellent tool as it allows the testing of new combat methods in war games or simulators. This extremely promising work should be carried out under the direction and guidance of the chiefs of staff and research branches of each service, which have sufficient experience and decision-making weight to guide the choices made by our armed services following a global analysis of the issues at stake in robotics integration.

More specifically for UGVs, taking the example of the same model as for human soldiers, the robots must first learn the basics such as "march" and "be ready to defend yourself". A simulation of such behaviour ahead of their development will avoid difficulties in their implementation or their rejection by experienced soldiers. The next stage consists of testing in the field, which also allows for testing how discreet the machines are; a crucial point in operational tactics, especially at night.

Risks to be taken into account

The digitalisation of the battlefield and the constant trend towards the integration of electronics into future military equipment (infantrymen with integrated communications gear,[18] vetronics, robots, remote sensors) will require management of the radio spectrum. As a consequence, automated systems thus bring with them new vulnerabilities, which should be taken into account and protected. They are particularly sensitive to jamming, and are completely unprotected from EMP (Electro Magnetic Pulses, which can destroy electronic devices and jam telecommunications signals). The instability of communications networks can lead to a loss of control, which can only be resolved by developing autonomous behaviour by these robots. The digital data used by the systems also need to be protected from cyberattacks. Faced with these vulnerabilities, it is in the design phase that engineers must integrate a minimum of security features, imagining the worst scenarios and the appropriate reactions of these machines, which can autonomously go from a return to its point of departure to self-destruction if necessary. Their integration on the battlefield depends on our capacity of protecting these automated systems, especially if we must face high-tech weapons. The risk is that we become dependent upon systems which can be rapidly neutralised by the enemy in the first minutes of an engagement.

CONCLUSION

Today, we are witnessing the first elements of a real revolution in the art of war. The reason is the digitalisation of military equipment, which allows for active remote operation of captors and effectors at any place on the battlefield, as well as for the reduction of the risk to combatants. These tools will progressively become intelligent and their use will dominate periods before military action to observe the enemy and anticipate his manoeuvres, then during the course of the battle to react more quickly and precisely than the enemy, all the while as the machines adapt to the terrain and conditions to accomplish the mission they were assigned.

Faced with this transformation of the means available to soldiers, the vision of the French Army is that robotics systems will continue to improve their operational capabilities on the battlefields of today and the future, but under the condition that military commanders have the mastery and control over them as well as the responsibility for the mission.[19] A first-rank high-tech army, the French Army is resolutely dedicated to robotisation.

To conclude, military robots certainly include a risk of occasional rejection by soldiers following the inevitable disappointments of initial robotics systems, especially when their performance in the field fails to meets expectations. Nevertheless, the revolution is underway and they should be progressively integrated into military action, supported by the reduction in the size of armed forces and future technological advances.

ENDNOTES

[1] The report is available in French via this link: https://fr.calameo.com/read/000558115a2727297e70a

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THE UNITED ARAB EMIRATES

Sintija Broka and Serge Lévitski

During the recent decade, we have witnessed tremendous growth in the use of electric vehicles in many fields, such as transport, logistics, agriculture, and military industry, presenting the growth of information technologies. Innovation on the military level is mostly driven by the threat perceptions which were initially equated to military power against actors' opponents. As the times are changing, a massive exchange of people, funds, and ideas between the international actors is beginning to determine the role of interdependence as well. Thereby, the late century and the last decades call for new thinking, and changing conditions requires customised theories and innovations. According to Kenneth N. Waltz, systematic changes are observed all the time, but some of them are more significant than others. Substantial changes in the field of transport, logistics, communication, and warfare have a considerable impact on how actors of the international system are interacting with each other.[1]

DIFFERENT GROUNDS FOR INNOVATION: DEVELOPING AMBITIONS

Assuming that international competition in an international anarchical environment directly determines the development of the military sector, structural realism indicates that the external security environment plays a vital role in the strategic choices of countries. Insecurity – the presence of external threats serves as a significant incentive for states to implement various innovations, including innovations in the military industry. So, the higher the level of insecurity, the stronger the incentive for countries to innovate.[2] At the same time, countries with growing international interests and ambitions will also be more interested in developing innovation, thus defending their interests, creating a regional environment and gaining a strategic asset for power generation. Under such circumstances, the nature of international relations contributes to mutual competition between countries in various aspects – military capabilities, successful innovations, organisational forms, practices, and technologies. As Waltz argues, "[t]he possibility that conflict will be conducted by force leads to competition in the arts and the instruments of force. Competition produces a tendency toward the sameness of the competitors."[3] Consequently, military innovation in the international system is united and hierarchical, with various innovations that gradually appear in the more developed countries and are slowly being absorbed into smaller national security strategies. In spite of the international unity of military modernisation, technologies can be also suited to the country's geopolitics, social structures, and available resources.

Robotics in the United Arab Emirates (UAE) are already involved in many areas and activities of everyday life, such as healthcare, infrastructure, education, military, security, aviation, home services, and others. Many experts and specialists in the field of robotics and artificial intelligence assert that robots and automation software will form the present and the future with enormous opportunities and potentials, as well as potential challenges.[4] The focus on innovations in the UAE is increasing rapidly. The government has contributed to such initiatives as the National Innovation Strategy to create a "competitive knowledge economy", *UAE Vision 2021*[5], and *Abu Dhabi Vision 2030*[6] – it is now a national strategy and a vital component of the country's economic environment. The military technology analysts B. Thomas and J. Lake are reminding of the so-called "Islamic Golden Age", a time when the Muslim world was considered the bedrock of global innovation, its significant scientific achievements drew people from around the world to study physics, mathematics, chemistry, biology and more under the guidance of well-renowned scholars. Fast forward to the 21st century; the UAE is leading the charge to bring innovation back to the nation. Since it declared its independence in 1971, the UAE has enjoyed outstanding growth and has become one of the world's richest and well-educated countries. The UAE has the second largest economy in the Middle East and now it is planning to spearhead a revolution to recapture its "legacy of innovation" as well.[7] Innovation as a key driver of economic growth and development is now widely recognised. According to the *UN's 2018 Global Innovation Index*,[8] the UAE ranked the 38th worldwide concerning overall performance on the index. Although the indicators have been declining since 2017, where the country held the 35th position, it remains number one in the Arab World and ranked 24th in the innovation input pillar. Besides, the country also demonstrates an increase in its innovation output pillar from 56th in 2017 to 54th in the year 2018.[9]

Being surrounded by two regional hegemons, it clear that the UAE is forced to develop its own military capabilities much faster, better and in a more sustainable fashion. As the UAE alliance behaviour suggests multi-vector relationships where Iran is seen as a regional threat, it is not the only player concerning the UAE capabilities. The Kingdom is interested in attracting as many foreign players as possible, maintaining close relations with Saudi Arabia and the Gulf Cooperation Council (GCC) partners as well as with the great powers from NATO and the European Union. At the same time, UAE alliances behaviour turns to Russia, China, and India. Besides, it is not just the regional dynamics that drive the UAE, it is also the level of ambitions that the kingdom is having. Through different infrastructure, finance, and real estate projects all around the world, the UAE continues to drive international tech ambitions. The kingdom is rapidly becoming the region's leading technology hub, attracting local and foreign entrepreneurs, and generating significant interest from investors. The purposes behind the innovation strategies are the following. The Emirates are looking forward to implementing a sustainable investment plan for human capital in the UAE, shifting the economic and social development away from the energy sector and enhancing the UAE's global standing through the introduction of corporate methodologies and culture of innovation.[10] The Kingdoms' authorities are ahead of the technology curve in the whole Arab world. They are cherishing bold ambitions and attracting the investors that are rapidly taking note and beginning to engage. At the same time, the whole great innovation strategy is designed to make the UAE one of the leading nations of innovation. The UAE government keeps discussing the importance of advancing innovation, research, and technology especially in the areas of defence, aerospace, and security. Key areas for innovation in the defence sector identified by the UAE include the aerospace. Increasing military activities and the UAE's willingness to use hard power is a trait for an active UAE foreign policy. The reason why the Emirati leadership has pursued such an aggressive foreign policy, especially in the region, is the same reason why the innovations in military terms must be developed.

Apart from the wide range of ambitions, UAE has relatively limited opportunities to realise all of them. The limits are based on two main questions. The most apparent concern is demographics. As migrants represent over four-fifths of the Emirates' inhabitants, it has a limited pool of local talents, and competition over talents among different local industries is considerable. Also, as in most of the Arab kingdoms, the lack of transparency of some of its defence products, deals, investments quite often even in performances is another challenge.[11]

UAE'S WAY TO THE FULL UNMANNED VEHICLE SECTOR DEVELOPMENT

The Middle East and North Africa are seen as quite unstable regions facing different kinds of challenges, and very often are called the most violent areas in the world. It is also recognised that the conflicts, such as civil wars in Libya, Iraq, Syria, and Yemen, as well as the instability in Egypt, the continuous power struggle between Iran and Saudi Arabia, and the growing extremism, attract different actors across the region and elsewhere. Many of these conflicts have turned into the proxy wars, where several actors involved are able to test their military capabilities against a real rival. UAE is not an exception. In recent years, the country has gained crucial front-line experience in Libya, Afghanistan, and Yemen, not to mention that in general, although the UAE's armed forces remain relatively small, they have played an influential role in all those conflicts.[12] The UAE has been a key player since the Saudi-led coalition started its war in Yemen in March 2015, including numerous ground clashes, naval attacks, and many more air campaigns. Even more, partly due to the country's multi-vector foreign policy, those military campaigns have been backed by the USA and several powers in the EU, such as France and the United Kingdom.

The UAE, while developing its differentiated and forward-thinking national economy, does not forget about strengthening its defence capabilities and national security. The increase in UAE military power is due to its involvement in various conflicts and its technological development, which has put the country in the leading position among today's high-tech weapons importers. As a result of industrialisation and modernisation processes, UAE's defence sector is involved in ambitious and rapid growth schemes of unmanned systems. Starting from the development of Unmanned Aerial Vehicle (UAV) technologies, the benefits of using highly autonomous Unmanned Ground Vehicles (UGVs) for the army in many areas are potentially high.[13]

In the kingdom, as elsewhere, heavy armour and firepower characterise the need to transform the traditional army into a lighter, more responsive force that is both lethal and survivable at once. Such a need for progress has made the development of practical UGV systems a necessity. In practice, UGVs are used as arms platforms, for transport support, surveillance, target acquisition, etc.; to increase efficiency and to reduce risks to soldiers.[14] For the Middle East in general, including the wealthiest kingdoms such as UAE, the Gulf region market is very important. The region's countries are greatly interested in introducing unmanned solutions as a new military capability.[15]

UAE stands among the top 15–20 defence spenders globally. Although the public data regarding the previous four years is quite limited, according to different public sources, UAE ranked in the 16th position in 2018.[16] Defence spending remained a relatively high share of the GDP. The situation is due to various factors including the role of the UAE in the operations of the Saudi-led coalition in Yemen, rising region extremism, and persistent tensions with Iran. At the end of 2014, the UAE experienced a significant sector reform. "U.A.E. government combined several defence and aerospace companies owned by Mubadala Development, Tawazun Holding, and Emirates Advanced Investment

Group (EAIG) into a single entity, Emirates Defence Industries Company (EDIC)."[17] EDIC is a national military industry leader, comprising a large number of companies operating in different military sectors: land, air, and marine.[18] The reforms carried out in 2014 and the establishment of the EDIC were a milestone in the efforts of the UAE to restrict its spending on defence, serving as an economic diversification pillar of the country's agenda. All 16 companies that were involved were spread across manufacturing, autonomous vehicles, navigation, maintenance, repair and modification, digital communications, logistics, and technology development.[19] It was hoped that EDIC's consolidated structure would provide enhanced value for its stakeholders, shareholders, partners, and clients, and would better position the company to serve and support the UAE Armed Forces and to win new business in the broader region. As an essential market, the UAE has been able to attract significant investment and technology transfer from a range of companies from outside the country.[20] Even if the public information shows that UAE primarily is focusing on UAV development and UGVs prototype development, lagging behind in international cooperation, the interest in different UGVs prototypes from the outside has been observed. In recent years we have seen that the UAE government has been interested in various modules of cooperation.

NEWBIES: UNOBTRUSIVE INTEREST IN FOREIGN PRODUCERS

Recently, the military equipment produced in the Emirates has made its way forward with contracts signed at the *Unmanned Systems Exhibition & Conference UMEX 2017* (and a year before that) in Abu Dhabi. Ten defence deals with a total value of 208.483 million euros were signed at the event. The deals were closed manly in the field of aircraft system support, purchase of spare parts for unmanned aerial vehicles, including technical and training support, however, a minor part of deals was related to weaponry systems.[21] In UAE government and defence sector developments, there has been a more in-depth focus on the UAV system developments, with a smaller focus regarding the UGVs. Nevertheless, according to the country's ambitions and valuable transactions in the field, it is just a matter of time until we will see the broad spectrum of cooperation in UGVs development. While we wait for that to happen, we can look at the technology listed below that has attracted interest for the UAE government.

In 2017, the Estonian defence company *Milrem Robotics* established a partnership with the defence industry of the UAE by signing an MoU with IGG Aselsan Integrated Systems (IAIS), a joint venture of the International Golden Group from UAE and Aselsan from Turkey. The former and *Milrem Robotics* are also developing a UGV platform for UAE's armed forces as well.[22]

Both sides are interested in launching a testing program in which the Emirates' soldiers will test the vehicle for capabilities.[23]

In March 2018, *Milrem Robotics* has announced the introduction of its next-generation THeMIS unmanned ground vehicle, specially designed for desert terrain and hot climates and equipped with independent capabilities. The new THeMIS is 30 cm long and has a much better capacity in desert conditions, as well as better cooling systems. The vehicle has a larger cargo space that can be used to transport various remote weapons systems,

Picture 1. THeMIS unmanned ground vehicle.
Source: Milrem Robotics

observation equipment, and other payloads. Weapon systems integrations on the THeMIS vehicle have been completed with *Singapore Technologies Kinetics, Aselsan,* and *FN Herstal*. According to the information, the THeMIS have been tested in the Arabian Desert climate and its terrain. The knowledge gained from those tests has been incorporated into the new version of the system. Mr Kuldar Väärsi, Chairman of the Board of *Milrem Robotics*, in an interview with the Emirates' News agency *WAM* characterised the Middle East as the ideal market for UGVs systems.[24] Along with the latest technologies and the production potential in the Gulf region, *Milrem Robotics* has an excellent opportunity to engage in the broader Gulf and Middle East military markets.[25]

In 2018, during *Unmanned Systems Exhibition & Conference UMEX 2018*, UAE officials have shown an interest in the Serbian unmanned ground platform *Miloš.*[26]

Picture 2: Unmanned Ground Vehicle "Miloš".
Source: Army Guide[27]

This vehicle is designed to support special forces and reconnaissance units, with a particular focus on counterterrorism operations in urban areas.[28] It can operate at a distance of 1 km apart from its operator. The vehicle gun provides up to 800 m of maximum effective range, and "the grenade launcher can effectively hit targets up to 400 m away."[29] Weighing 650 kg, the UGV vehicle can continuously be involved in operations for one hour, built-in batteries provide sufficient power. Tests are proving that this UGV can reach a speed of 7 km/h.[30] "The typical role of *Miloš* is to conduct reconnaissance of the battlefield, and it can also be used as an anti-tank weapon, although in the latter case it is necessary to replace the combat module with the ATGM [anti-tank guided missile]."[31]

After the already mentioned *Unmanned Systems Exhibition & Conference UMEX 2018* in Abu Dhabi, the improved 8×8 "Phantom-2" UGV aroused the interest of the UAE officials. "The vehicle is being developed by Ukraine's state-owned defence holding, UkrOboronProm. "Phantom-2 has a gross vehicle weight (GVW) of 2600 kg with the

Picture 3. 8×8 Phantom-2 unmanned ground vehicle.
Source: Denis Fedutinov, bmpd.livejournal.com[34]

possibility to mount various types of weapons (machine gun, grenade launcher, ATM, etc.) and additional modules."[32] "The vehicle is controlled by a secure radio channel with a maximum range of 10 km from the operator or from a fibre optic cable up to 5 km from the operator."[33]

Going through the latest UGV innovations in UAE's Armed Forces, it is clear that the development of UAV for military purposes is moving ahead of the development of UGV. Meanwhile, it is clear that, taking into account the nation's ambitions and great potential for using unmanned instruments, in the nearest future we will face a rapid expansion of production of unmanned ground vehicles. Although the Emirati Defence Technology Industrial Base (DTIB) is a newcomer compared to those of its regional counterparts, e.g. Egyptian and Saudi Arabian, the UAE is becoming a perspective emerging arms producer.[35]

Critical areas for innovation identified by the UAE include the aerospace and defence industries. Innovation in these areas has already realised the additional benefits of freeing the UAE Armed Forces from some of their reliance on imported equipment and technology. Also, as part of UAE's plans for a post-oil and diversified economy, the UAE is focused on building a local manufacturing base to decrease its dependence on Western arms' manufacturers. One of the factors describing faster UAVs system development can be the history of UAE's armed force development. In 1967, the sea wing of the Abu Dhabi

Defence Force was established, with a command position at the current location of the Abu Dhabi Navy. The Air Force was established right after, in 1968. Meanwhile, the establishment of UAE's Land Forces Command took place only in 1989.[36] Another factor that follows the first one is that the cooperation in different missions has been stated according to UAE's armed force capabilities. Self-evident is the fact that the capacity in certain unmanned vehicle sectors is being developed according to the actual needs. However, at the same time, taking into account the nation's colossal ambition to become a world leader in many ways, in upcoming years we will see rapid growth in UGV product development. The first insights into these developments could be gained during the next *International Defence Exhibition in Abu Dhabi (IDEX)*, which will be held in February 2019.

Apart from showing an interest in cooperation with foreign partners concerning the UGVs production and import, and regarding the main focus on UAV development, UAE's defence sector slowly, but steadily is working to develop ground system capabilities. The UAE's defence sector development does not stop at the UGVs or UAVs systems development; the country is actively developing other areas as well. The UAE is continuing to integrate new weapons, systems, and sensors on its aircraft and helicopters, keeping them viable and effective. In most cases, this has involved new armaments as well, through the Emirates are making efforts to establish an indigenous weapons development and manufacturing capability.

IN LIEU OF CONCLUSIONS. UNCLEAR ACHIEVEMENTS: ONLY FOR THE TIME BEING

According to basic theory, the higher the level of insecurity, the stronger the willingness for countries to grow and innovate. Different states, including the UAE, have never hidden their broad ambitions both regionally and internationally. So, in this case, it is not just the threat perception that works as a driver to develop – in the case of the UAE, among others, it is indeed the country's growing international interests and ambitions that are driving the government to its innovation strategies. Through innovation in various fields, including the UGVs system development, and through widening international cooperation in the field, UAE is defending its interests via creating a regional environment and gaining a strategic asset for its power generation.

Motivated by strategic, economic, and symbolic ambitions, the UAE attempts to invigorate its whole defence industry, and, definitely, they are on the right track. Unlike other Arab states which are seeking to develop their defence industries, the UAE approaches the task as a whole complex that also includes developing its potential export capabilities and building a strong partnership with foreign partners. With larger foreign exchange reserves than most of the European states and the oil reserves management, UAE has the capital and political will to fund and develop a strong and capable defence industry complimented with the latest innovations in order to avoid any loss of the soldiers and to keep its place on the global stage.

If the UAE wants to compete on the global stage, on one hand, it has to achieve a significant progress. On the other hand, the transparency issue must be improved. For international partnership building processes, annual IDEX conferences are an essential element. At the previous IDEX exhibition, several memorandums of understanding where signed in the field of research, development, and production expertise. In this respect, the UAE's regional positions have been improved.

At the same time, with the development of international cooperation, such as *Milrem Robotics* involvement in the Gulf region, we can expect not just more transparency during the process development, but even more rapid development of UGVs systems. At the same time, for saving their position in the region and promoting government revenues, we have taken into the account that the kingdom is looking for the arms' export opportunities. In the future, we could observe that more emphasis could be on local technical solutions, which are likely to become more important and significant.

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THE UNITED KINGDOM

James Rogers and Robert Clark

FUTURE ROLE OF UGVS: VISION AND DEVELOPMENTS

The United Kingdom's (UK) current vision for the future role of Unmanned Ground Vehicles (UGV) originates from the British Army's "Strike Brigade" concept, as outlined in the *Strategic Defence Security Review 2015*.[1] This review proposed that British ground forces should be capable of self-deployment and self-sustainment at long distances, potentially global in scope. By 2025, the UK should be able to deploy "a war-fighting division optimised for high intensity combat operations"; indeed, "the division will draw on two armoured infantry brigades and two new Strike Brigades to deliver a deployed division of three brigades."[2] Both Strike Brigades should be able to operate simultaneously in different parts of the world.

The ability for land forces of this size to self-sustain at long range places an increased demand on logistics and the resupply chain of the British Army, which has been shown to have been overburdened in recent conflicts. This is likely to increase due to the evolving nature of warfare and the environments conflicts are likely to occur in. These environments are likely to become more "cluttered", "congested" and "contested" than ever before.[3] Therefore, a more agile and flexible logistics and resupply system, able to conduct resupply in a more dynamic environment and over greater distances, is required to meet the challenges of warfare from the mid-2020s and beyond.

This will represent something of a shift in the UK's vision for UGV technology, having previously been utilised almost exclusively for Explosive Ordnance Disposal (EOD) and Countering-Improvised Explosive Devices (C-IED)[4] for both the military and the police, as opposed to being truly a force-multiplier developing the logistics and resupply chains. EOD and C-IED UGVs have been used by the UK for many years, and new versions have been developed continuously – with the T7 due to enter service very shortly.[5]

The Ministry of Defence's Defence Science and Technology Laboratory (DSTL) is developing this vision further, currently leading a three-year research and development programme entitled Autonomous Last Mile Resupply System (ALMRS).[6] This research is being undertaken to demonstrate system solutions which aim to reduce the logistical burden on the Armed Forces, in addition to providing new operational capability and to reduce operational casualties. Drawing on both commercial technology as well as conceptual academic ideas – ranging from online delivery systems to unmanned vehicles – at least 140 organisations submitted their proposals.

The first phase of programme provided a challenge to provide innovative technology to support and supply war-fighters on the front,[7] working with research teams across the UK and internationally. This highlights the current direction with which the British vision is orientated regarding UGVs, i.e., support-based roles. Meanwhile, the second phase of the ALMRS programme started in July 2018 and is due to last approximately twelve months.[8] It will include "Autonomous Warrior", the Army Warfighting Experiment 18 (AWE18), a 1 Armoured Infantry Brigade battlegroup-level live fire exercise, taking place at Salisbury Plain in November 2018. This will see each of the five remaining projects left in the ALMRS programme demonstrate their autonomous capabilities in combined exercises with the British Armed Forces, the end user. This will provide DSTL with user feedback, crucial to enable subsequent development; identifying how the Army can exploit developments in robotics and autonomous systems technology through capability integration.

Among the final five projects short-listed for the second phase of ALMRS and AWE18 is a UGV multi-purpose platform called TITAN, developed by a British military technology company QinetiQ, in partnership with Milrem Robotics, an Estonian military technology company. Developing its Tracked Hybrid Modular Infantry System (THeMIS), the QinetiQ-led programme is expected to impress in the upcoming AWE18.

The THeMIS platform is "designed to provide support for dismounted troops by serving as a transport platform",[9] a remote weapon station, an Improvised Explosive Device (IED) detection and disposal unit, and surveillance and targeting acquisition system designed to enhance commanders' situational awareness. THeMIS is an open architecture platform, with subsequent models based around a specific purpose or operational capability.

THeMIS Transport is designed to manoeuvre equipment around the battlefield to lighten the burden of soldiers, with a maximum payload weight of 750 kg.[10] This would be adequate to resupply a platoon's worth of ammunition, water, rations and medical supplies and to sustain it at 200% operating capacity – in essence, two resupplies in one. In addition, when utilised in battery mode it is near-silent and can travel for up to ninety minutes. When operating on the front-line, this proves far more effective that a quad bike and trailer, which are presently in use with the British Army to achieve the same effect. This is often overseen by the Platoon Sergeant, the platoon's Senior Non-Commissioned Officer and most experienced soldier. Relieving this individual of this burden would create an additional force multiplier during land operations.

THeMIS can also be fitted to act as a Remote Weapons System (RWS), with the ADDER version equipped with a .51 calibre Heavy Machine Gun (HMG), outfitted with both day and night optics.[11] Additional THeMIS models include the PROTECTOR remote weapon system, which integrates Javelin anti-tank missile capability. Meanwhile, more conventional THeMIS models include GroundEye, an EOD UGV, and the ELIX-XL and KK-4 LE, which are surveillance platforms that allow for the incorporation of remote drone technology.[12]

BRITISH ARTIFICIAL INTELLIGENCE (AI) POLICY

The development of effective UGV technology is dependent on research and development in three critical areas: robotics; truly automated control systems; and Artificial Intelligence (AI). Robotics is an industry which has seen much recent development, not just in the UK, but also internationally, especially in the USA and in Japan. However, the movement towards fully automated control systems – especially if armed – requires much more research in the realm of AI, particularly regarding moral and legal issues. Due to its dynamic academic and research culture, and internationally leading AI companies, the UK is in a position to be one of the global leaders in the development of AI. In this sense, the House of Lords' Select Committee on Artificial Intelligence issued a report on British AI policy in June 2018 pointing to the fact that the UK needs to resolve various ethical issues to remain a market leader in AI research.[13] This report recommends "that the Government convene a global summit of governments, academia and industry to establish international norms for the design, development, regulation and deployment of artificial intelligence."

THE INFLUENCE OF UGVS ON THE CAPABILITIES AND TACTICS OF SMALL INFANTRY UNITS

To understand how UGVs will influence the capabilities and tactics of small infantry units in the coming years, it is important to understand the different types of infantry units in service in the British Army. There are currently 33 regular British Army infantry battalions, comprising 500 approximately personnel each, with each one specialising in one of the following roles: light-role; mechanised; or armoured warfare. The breakdown of these are: 22 light-role battalions; six armoured battalions; and five mechanised battalions.[14]

Light-role battalions by definition do not operate in vehicles and are trained instead to move and fight primarily on foot, although this often changes on operations. Mechanised battalions have access to vehicle-born weapons platforms, currently either Jackal 2 or Foxhound, which provide a moderate troop transporting capacity. Armoured battalions have access to armoured personnel carriers and the Warrior, a heavily armed and armoured vehicle, capable of delivering the infantry dismounts inside into the heart of modern battle, ensuring that they arrive safely and have a strong fire-support base from which to launch their attack.

It is worth noting that in both the mechanised and armoured roles, infantry battalions are relatively self-sufficient in the manner of both direct and indirect fire support, and of logistics and resupply – the two areas where UGVs have the most utility for an infantry battalion.

There is far greater potential for the development of UGVs within a light-role infantry battalion, due to the fact that their organic fire support and resupply systems are man-portable, limiting the effect they can achieve, unless reliant on external units for support, such as for transport. Therefore, this analysis will seek to determine how UGVs can influence the capabilities and tactics of light-role infantry units.

In analysing UGV influence on the tactics of light-role infantry battalions, it is necessary to determine their battlefield roles. Infantry battalions have two overall roles in battle: offensive, and defensive. These can be further broken down into further mission-specific roles, as required, though for the most part, these fall into these two operational vectors. By analysing each in turn, it is possible to further delineate how UGVs can influence the capabilities and tactics of light-role infantry battalions.

Offensive: in an offensive environment, UGV capability can be utilised in two dominant roles. The first includes RWS and direct fire-support, while the second involves a support role within the transport and re-supply chain.

While there remains much room for discussion surrounding the ethical implications and employment of RWS in today's conflicts, there is certainly a requirement for this capability, and it boils down almost exclusively to manning. During a deliberate attack on a fortified enemy position, an RWS platform – such as the THeMIS ADDER with a Heavy Machine Gun (HMG) – can provide direct fire-support which would normally require either a mechanised platform such as Jackal 2 or MASTIFF, or a 2-3 man HMG crew, with accompanying quad bike and trailer. In a light-role configuration, the mechanised platform is clearly inappropriate, leaving the only viable option for such a battlefield effect requiring a 3-man team plus vehicle.

This situation is replicated with other light-role infantry weapon systems, including the 40mm Grenade Machine Gun (GMG) and even the 81mm mortar. If UGV technology can be utilised to fulfil these additional direct and indirect fire roles, then this would greatly free up manpower.

There is a further advantage of utilising UGVs in this role. During an offensive operation, whenever the battle moves forward, then so does the fire support. If this is coming from a static 3-man fire support team, then this will have to cease activity whilst dismantling the weapon system, moving forwards to a new position, and setting it back up again. This is not only time consuming but will leave long periods without fire support and thus leaving ground forces vulnerable. Clearly, UGV platforms in this capacity, from a purely operational perspective, would provide great utility and cut down considerably on manning requirements, freeing-up other ground troops to other parts of the battlefield.

The transport and resupply chain can also be enhanced during offensive operations. During this phase of operations, there are often many offensive actions coordinated simultaneously, stretching the resupply chain to its limit. Again, this comes down to manning and equipment: often there are simply too few personnel available, with limited transport capacity, to facilitate a light-role infantry battalion. This can result in a variety of scenarios ranging from time wastage to sub-unit combat ineffectiveness.

The THeMIS transport platform can transport small numbers of personnel around the battlefield, at a much higher pace than by foot, serving several key objectives. This is ideal for extracting casualties back to receive treatment, which in battle is conducted by a four-man team per casualty, and then by a battlefield ambulance operated by a minimum of two personnel.

For example, in an incident involving two casualties requiring extraction, ten personnel would normally be utilised. This is a labour-intensive process removing personnel from battle, often during critical moments. To mitigate against this, a THeMIS transport platform could be set remotely for pre-designated waypoints and can carry at least two casualties, and at a much higher pace of extraction than by foot. Not only does this potentially result in a casualty being extracted much quicker to receive treatment, it additionally frees up vital manpower during the battle.

Defensive: in defensive operations, Infantry battalions may be required to hold key terrain for a prolonged period of time. This has a limiting effect on other capabilities, which commanders may seek concurrently. For instance, the ability to hold a piece of key terrain or ground would require a surveillance capability in addition to the ability to defend the ground through weapons considerations.

In order to achieve this, these tasks require manpower which cannot be used in other battlefield roles while conducting defence, such as patrols undertaken by sub-units on foot. Therefore, UGV technology could be utilised as a surveillance asset at certain pieces of key terrain, in addition to a RWS to guard that piece of key terrain against enemy attacks, with largescale area denial achieved by emplacement of interlocking weapon systems (THeMIS ADDER with mounted GMG and HMG with ranges of 2 km or more).

The combination of a THeMIS ELIX-XL with an ADDER RWS would provide this capability and thus reduce manpower at critical points on the ground, while simultaneously conducting defensive operations, with an ELIX-XL drone having the capability to be autonomously launched and recovered by the UGV Drone Nest.[15]

This ability also reduces the need to launch standing patrols between the enemy's defences and the defences of friendly forces – a key infantry task whilst operating in defence. The ELIX-XL surveillance platform incorporates a real-time video from two on-board cameras and an on-board video recorder. In addition, it provides a fully autonomous flight control system and an autonomous mission execution control system, with the ability to select active waypoints and change the coordinates *in flight*.

Weather and optics dependent, this battlefield asset would be able to achieve highly comparable results with a small reconnaissance patrol. These patrols, encompassing eight individuals, are often launched in sequence, comprising three separate patrols at a time. The ELIX-XL has the ability to switch drone batteries, minimising the time between flights. This surveillance capability would therefore be able to theoretically conduct the same workload as an infantry platoon (comprising 30 soldiers), while operating standing patrols during a defensive phase of operations, further freeing up manpower across the infantry battalion to conduct other mission-specific tasks.

THE MAIN CHALLENGES WITH INTRODUCING UGV IN COMBAT FUNCTIONS

Like with other military forces, the main challenges to the further introduction of UGVs within the British Army can be broadly grouped around four key themes: operational, institutional, financial, and legal. If the UK is to maintain its momentum in pioneering the utility of UGV, it should take these challenges seriously. Indeed, the UK should embrace each challenge, viewing every one as an opportunity to strengthen its global role in this field.

Operational: while the proposed merits of utilising UGV in combat functions by infantry units have been discussed above, it is only through extensive trials of UGV within these ground units that a more accurate and reliable assessment can be made regarding the fulfilment of this potential utility. Seeking to build on the success of the Royal Navy-led Unmanned Warrior exercise in 2016, the DTSL and British Army-led Army Warfighting Experiment – Armoured Warrior – will seek to push the existing boundaries of technology and military capability in the land environment during an extensive month-long exercise with 1 Armoured Infantry Brigade in November 2018. This should allow time for the operationalisation of the various UGV capabilities. Crucially, this will enable the technology to be run by the desired end-user, British infantry, and provide critical operational information developing UGV further into Army 2020 and beyond.

Institutional: it can often take time for policy to transition from the strategic space to the operational space, and institutional barriers can elongate this process further still. In his first major speech as the Chief of the General Staff, General Mark Carleton-Smith stated – "the nature of warfare is broadening beyond the traditional physical domains," adding "that 21st Century battlefield requires non-traditional skills (…)."[16] Moreover, he stated the need to place "some big bets on those technologies that we judge may offer exponential advantage because given the pace of the race, to fall behind today is to cede an almost unquantifiable advantage from which it might be impossible to recover."[17] The challenge is therefore to implement this strategic outlook down the military chain, to the end-user, i.e., infantry battalion commanders. Through continued integration of UGV into brigade-level and below training exercises, the exposure this will give these sub-unit commanders will significantly reduce the institutional gaps between strategic doctrine and operational delivery.

Financial: UGV technology is expensive to fund, though there are multiple avenues for research and development. On 16 September 2016, the UK Secretary of State for Defence launched the Defence Innovation Initiative (DII).[18] This is an £800 million fund designed to increase the pace of development of various projects for defence, aimed at the private sector, in addition to academia and research institutions. Autonomous Warrior and the UGV technology pioneered through the programme is funded by the DII and seen as integral to the future development of both British defence and industry.

Legal: the "discussion on legality, ethics and meaningful human control with the reality of weapon systems development and weapon"[19] use needs further exploration. To begin with, refocusing the legality discussion to one of the "development of 'autonomy in weapon systems' rather than autonomous weapons or laws as a general category"[20] would be of benefit. In addition, by shifting the focus away from complete autonomy and exploring instead how autonomy transforms human control, greater engagement will be seen from various stakeholders likely to raise issues of legality regarding full autonomy. Furthermore, every effort should be made by the UK government to engage with the Convention on Certain Conventional Weapons (CCW) regarding the development of UGV technology and the legal implications of autonomy in weapon systems on the battlefield. By seeking to actively engage with the CCW on these matters, the UK can ensure it maintains its global role further in the continued development of UGV and RWS, as well as their subsequent implementation and operationalisation.

FUTURE REQUIREMENTS FOR UGV RELATED RESEARCH AND DEVELOPMENT

Given that UGV technology is still in its infancy, it is likely that emphasis will continue to be placed on the gradual improvement of the technology. In addition, the ongoing replacement of manned positions and tasks in the British Army (and other armed services), particularly in those areas where the least "resistance" is offered, i.e., where it is easiest to replicate a human task with a UGV, is likely to continue. It is also likely that UGVs will be sought in the most dangerous of missions, although this need may be complicated by the relative lack of intelligence of UGVs in comparison to their human equivalents.

However, the development of other unmanned systems in the air and at sea – which may be able to better fulfil roles undertaken previously by ground forces and logistics systems – may ensure that some UGV functions are short-lived. Nonetheless, UGVs are here to stay for the foreseeable future in the British Army: irrespective of what they do, they will become increasingly vital to modern combat operations, both in terms of fighting, surveillance, and logistics.

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