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Trends and Implications of Military Robotics

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An Analysis from the Swiss Perspective

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List of acronyms

4IR	Fourth Industrial Revolution
AAR	After Action Review
AAW	Anti-Aircraft Warfare
ACT	NATO Allied Command Transformation
AD	Active Defence
ADF	Australian Defence Force
AI	Artificial Intelligence
AID	French Defence Innovation Agency
AMS	Chinese Academy of Military Science
ANN	Artificial Neural Network
APC	Armoured Personnel Carrier
ARCHE	Advanced Robotics Capabilities for Hazardous Environment
ARDET	Advanced Robotic Detachment
ARF	Advanced Research Foundation
ASL	Autonomous Systems Lab at ETHZ
ASPIRO	Association for Swiss Industry Participation in Security and Defence Programmes
ATITC	Advanced Technologies for Industry Technology Centre
AU	Polish Armament Agency
AUKUS	Australian, UK and US Trilateral Security Agreement
BDC	Base Defence Concept
C2	Command and Control
C3	Command, Control and Communication
C4	Command, Control, Communication and Computer
C4ISR	Command, Control, Communication, Computer, Intelligence, Surveillance and Reconnaissance
CAGR	Compound Annual Growth Rate
CAS	Chinese Academy of Science
CBRN	Chemical, Biological, Radiological and Nuclear
CCP	Chinese Communist Party
CD&E	Concept Development & Experimentation Programme
CDTR	Centre for Digitalisation and Technology Research
CID	Italian Defence Innovation Centre
CIH	Cyber Innovation Hub
CIMCD	Commission for Integrated Military and Civilian Development
CMC	Central Military Commission
CNTBT	Comprehensive Nuclear Test Ban Treaty
CODIFI	Co-Investment Defence Innovation Centre
CoHoMA	French Army's « Coopération Homme-Machine »
COMSEC	Communications Security Agreements
CONOPS	Concept of Operations
CPoW	NATO Collaborative Programmes of Work
DAR	Estonian Department of Applied Research
DARPA	Defense Advanced Research Projects Agency
DASA	Defence and Security Accelerator
DATE	Decisive Action Training Environment
DBRD	Directorate for Defence and Development
DCAM	Spanish Direction General of Armament and Material

DCB	Defence Capacity Building
DCSIT	US Army Research Laboratory
DEFTECH	Defence Future Technologies or the Cyber-Defence Days
DG DEFIS	Directorate-General for Defence Industry and Space
DGA	French General Armament Direction
DI	Polish Department of Innovation
DIANA	Defence Innovation Accelerator for the North Atlantic
DIAS	Drone Industry Association Switzerland
DIB	Defense Innovation Board
DIF	British Defence Innovation Fund
DIH	Defence Innovation Hub
DIU	Defense Innovation Unit
DL	Deep Learning
DrOID	French Defence Innovation Reference Document
DSTL	Defence Science and Technology Laboratory
DUTE	Dual Use Technology Exploitation
ECDI	Estonian Centre for Defence Investment
EDA	European Defence Agency
EDAIA	Estonian Defence and Aerospace Industry Association
EDAP	European Defence Action Plan
EDEM	European Defence Equipment Market
EDF	European Defence Fund
EDIDP	European Defence Industrial Development Programme
EDRIN	European Defence Research Innovation Network
EDT	Emerging Disruptive Technology
EEP	Swiss armed forces' « Etudes de projets, essais et préparatifs d'achats »
EII	European Intervention Initiative
EM&E	Spanish Association of Mechanics and Engineering
EOD	Explosive Ordnance Disposal
EOP	Enhanced Opportunity Partner
ERA	Russian Technolopolis Technology Complex in Anapa
ERCoE	Expeditionary Robotics Centre of Expertise
ESG	MCDC Executive Steering Committee
EUDIS	European Union Defence Innovation Scheme
FBI	Federal Bureau of Investigation
FCAS	Future Combat Air System
FCG	Future Capability Group
FCIC	Frontline Command Innovation Centre
FD	Forward Defence
FDFA	Swiss Federal Department of Foreign Affairs
FFI	Norwegian Defence Research Establishment
FHS	Swedish Defence University
FID	French Innovation Defence Fund
FIS	Swiss Federal Intelligence Service
FMW	Swedish Defence Material Administration
FOI	Swedish Defence Research Agency
FSi	Norwegia Association of Defence Companies
FYP	Five Year Plan
GCAP	Global Combat Air Programme
GPS	Global Positioning System
HALE	High Altitude Long Endurance UAV

HEDI	Hub for European Defence Innovation
IAI	Israel Aeropsace Industry
ICBM	Intercontinental Balistic Missile
ICPC	NATO Individual Partnership Programme for Cooperation
IDF	Israel Defence Forces
IEEE	Institute of Electrical and Electronics Engineering
IFRF	International Federation of Robotics Frankfurt
IFV	Infantry Fighting Vehicle
IIT	Italian Technology Institute
INF	NATO Innovation Fund
INTA	Spanish National Institute of Aerospatial Technology
IRIU	Innovation Research Insight Unit
ISL	Franco-German Research Institute at Saint-Louis
ISR	Intelligence, Surveillance and Reconnaissance
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
ITTP	NATO Individually Tailored Partnership Programme (ITPP)
JALLC	NATO Joint Analysis & Lessons Learned Centre
JCPOA	Joint Comprehensive Plan Of Action
JSB	NATO Joint Support Branch
JWC	NATO ACT Joint Warfare Center
KSA	EDA Key Strategic Area
LAWS	Lethal Autonomous Weapon Systems
LIS	Laboratory of Intelligent Systems at ETHZ
MALE	Medium Altitude Long Endurance UAV
MARIN	Dutch Maritime Research Institute
MATE	Marine Advanced Technology Education
MCDC	Multinational Capability Development Campaign
MCF	Military Civilian Fusion
MCM	Mine Counter Measure
MCWL	Marine Corps Warfighting Laboratory
METT	NATO Mobile Expert Training Teams
MGCS	Main Ground Combat System
MKZ	Military Competence Centre of the Swiss Armed Forces
MIFIK	Milrem Intelligent Function Integration Kit
MILAK	Swiss Military Academy at ETHZ
MUAAR	MCDC Military Uses of Artificial Intelligence, Automation, and Robotics
MUM-T	Manned-Unmanned Teaming
NATO	North Atlantic Treaty Organization
NCCR	Swiss National Centre of Competence in Research
NGRC	Next Generation Rotorcraft Capability
NGW	New Generation Warfare
NIAG	NATO Industrial Advisory Group
NLR	Dutch National Aviation and Aerospace Laboratory
NORDEFCO	Nordic Defence Cooperation
NPT	Non-Proliferation Treaty
NSO	NATO Standardization Organization
OCC	Operational Capability Concepts
NSPA	NATO Support and Procurement Agency
OCEAN	Open Cooperation for European Maritime Access
OECD	Organisation for Economic Co-operation and Development
OODA	Observe, Orient, Decide, Act loop

OSCE	Organisation for Security and Cooperation in Europe
PADR	Preparatory Active Defence Research
PARP	NATO Partnership for Peace Planning and Review Process
PfP	NATO Partnership for Peace
PGZ	Polish Armament Group
PII	NATO Partnership Interoperability Initiative
PLA	People's Liberation Army
PNRM	Italien National Military Research Plan
PRC	People's Republic of China
PRP	NATO Planning Review Process
PTECs	NATO Partnership Training and Education Centers
RAS	Robotic Autonomous System
R&D	Research and Development
RCV	Robotic Combat Vehicle
RDT&E	Research, Development, Test and Evaluation
RF	Russian Federation
RICO	Robotic & Autonomous Systems Implementation and Coordination Office
RMA	Revolution in Military Affairs
RPAS	Remotely Piloted Aerial System
ROV	Remotely Operated Vehicle
RL	Reinforcement Learning
RTRC	Research and Testing Robotic Centre
RUAG MRO	RUAG Maintain, Repair and Overhaul
SDAM	French Navy UAV System
SDI	Strategic Defense Initiative
SDRZ	Swiss Drohnen und Robotik-Zentrum
SEFRI	State Secretariat of Education Research and Innovation
SIB	Special Intelligence Battalion
SLAM	Simultaneous Localisation and Mapping
SMDM	French Navy Micro UAV System
SME	Small-to-Medium size Entreprise
SNRF	Swiss National Research Fund
SOFF	Swedish Security and Defence Industry Association
SOG	Swiss Officer Society
S&T	Science and Technology
STANAG	NATO Standardization Agreement
SWATH	Small Waterplan Area Twin Hulls
TAI	Turkish Aerospace Industries
TDF	Territorial Defence Force
TMP	Technical Modernization Plan
TFEU	Treaty on the Functioning of the European Union
TNO	Dutch Association for Applied Scientific Research
TPNW	Treaty on the Prohibition of Nuclear Weapons
TRL	Technology Readiness Level
TSMC	Taiwan Semiconductor Manufacturing Company
UAV	Unmanned Aerial Vehicle
UCAV	Umanned Combat Aerial Vehicle
UGID	Italian General Defence Innovation Office
UGV	Unmanned Ground Vehicle
UKIR	UK Research and Innovation
USV	Unmanned Surface Vehicle

USA	United States of America
UUV	Unmanned Underwater Vehicle
UMS/V	Unmanned Maritime Systems/Vehicles
UNIDIR	United Nation Institute for Disarmament Research
VTOL	Vertical Take-Off and Landing
XLUUV	Extra Large Unmanned Underwater Vehicle

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Chapter 1: Definition and trends of robotics

Introduction

This study mandated by the Swiss Drone and Robotics Centre (SDRC/SDRZ) analyses the trends and implications of military robotics. This project aims to enhance understanding in the realm of military robotics and its impact on armament trends and policies. Overall, the study sheds light on the intersection of technology and security, equipping Switzerland to navigate the evolving landscape of military robotics effectively.

This study maps the global and European landscape of military robotic systems' research and development (R&D) and deployment capabilities. While focusing primarily on Europe and Switzerland, the research delves into the evolving landscape of military robotics, offering insights into capabilities across different European countries. A close analysis of ten European countries based on primary and secondary sources permits a comparative assessment of Switzerland in the field of military robotics.

The goal is to provide the SDRZ with practical recommendations that inform the strategic planning, procurement strategies, and military doctrine of the Swiss armed forces. The project is divided into four parts: Chapter 1 defines and classifies military robotic systems, Chapter 2 evaluates the international competition for capabilities in military robotics, Chapter 3 measures European developments of military robotics, Chapter 4 assesses Switzerland's developments in military robotics. Chapter 5 provides recommendations for Switzerland's doctrine, procurement projects, and development capabilities in military robotics.

Definition of robots

Robots are programmable machines that can operate automatically and perform automated actions based on their computer-based algorithm.[1] A robot is *"A powered machine capable of executing (…) actions by direct human control, computer control, or both. It is composed minimally of a platform, software, and a power source."*[2] According to the Institute of Electrical and Electronics Engineers (IEEE)[3] a robot is *"an autonomous machine capable of sensing its environment, carrying out computations to make decisions, and performing actions in the real world."*[4] The physical shape of robots *"consists of homogeneous, hierarchical components such as structures, gears, links, and joints that are interfaced by sensing and computer systems, but lack the tight integration of sensing and computation that biological systems exhibit"*.[5]

First, robots need to sense and detect the environment in which they operate. They are machines that operate within the paradigm of sensing-thinking-acting paradigm.[6] At the basic

[1] Shaw, Ian. "Robot Wars: US Empire and geopolitics in the robotic age", *Security Dialogue*, Vol. 48 Issue. 5, 2017.: 452.
[2] Feickert, Andrew et al., "U.S. Ground Force Robotics and Autonomous Systems (RAS) and Artificial Intelligence (AI)", *Congressional Research Service*, No. 45392, 2018.: 2; Bianca Torossian et al., "The Military Applicability of Robotic and Autonomous Systems", *The Hague Centre for Strategic Studies (HCSS)*, 2021.: 5.
[3] Institute of Electrical and Electronics Engineers (IEEE), https://www.ieee.org/. (Accessed on 13.02.2023)
[4] Guizzo, Erico. "What is a Robot?", *Institute of Electrical and Electronics Engineers (IEEE)*, 2018.
[5] Hughes, Dana et al., "Materials that make robots smart", *The International Journal for Robotics Research*, Vol. 38, Issue 12-13, 2019.: 1338.
[6] Singer, Peter. *Wired for War: The Robotics Revolution and Conflict in the 21st Century*, 2009.: 67.

level, robots can be divided into three families: (1) automatic; (2) automated and (3) autonomous systems. This distinction depends on the complexity of the tasks that can be performed by the system, which directly depends on the level of intelligence of the robot.[7] Therefore, robots are platforms that require a given input from their environment, or their operator to perform a task or multiple tasks.[8] They interact with their environment based on perceptions and execute plans according to their predefined computational program/algorithm.[9] Sensors enable the robot(s) to perceive their environment through various inputs.[10] Through the sensors, they observe their environment, compile information and take action. In return, they form a feedback loop called the perception-action loop, designed for robots that function autonomously in environments previously *unknown* to them.[11] Table 1 in the Appendix illustrates the different typologies in terms of the autonomy of military robotic systems.

Second, the scale of autonomy of robots determines their ability to operate and execute tasks. Autonomy has been defined *as "(…) the ability to perform an intended task without human intervention using the interaction of sensors and computer programming with the environment."*[12] It allows robots to be "self-governing" in executing tasks.[13] The input perceived through the robot sensors is processed in the robot's programme.[14] Autonomy manifests itself in the independence conceded by human operators to robots in the execution of these tasks. So, it enables the robot to *"achieve an assigned task based on the system's situational awareness, planning, and decision making."*[15] As Table 1 illustrates, autonomy refers to a spectrum on which various levels of interaction exist between the robot and the human operator.[16] Currently, there is no standard taxonomy of automation in robotic systems.[17] Generally speaking, there can be identified a three-levelled taxonomy of (1) semi-autonomous, (2) human-supervised autonomous, and (3) fully autonomous robotic systems.[18]

[7] Scharre, Paul. *Army of none: autonomous weapons and the future of war*. First edition. New York ; London: W. W. Norton & Company, 2018.: 31.
[8] Singer, Paul. "Outsourcing War to Machines: The Military Robotics Revolution", *ABC CLIO*, 2018.: 5.
[9] Sünderhauf, Niko et al., "The limits and potentials of deep learning for robotics", *The International Journal of Robotics Research*, Vol. 37, Issue 4-5, 2018.: 406.
[10] Yang, Ghuang-Zhong et al., "The grand challenges of Science Robotics, Science Robotics", Vol. 3, Issue 14, 2018.: 5.
[11] *Ibid.*
[12] Verbruggen, Maaike and Boulanin, Vincent. "Mapping the Development of Autonomy in Weapon Systems", *Stockholm International Peace Research Institute (SIPRI)*, 2017.: 5.
[13] Feickert, Andrey et al., "U.S. Ground Force Robotics and Autonomous Systems (RAS) and Artificial Intelligence (AI)", 2018.: 2.
[14] Verbruggen, Maaike and Boulanin, Vincent. "Mapping the Development of Autonomy in Weapon Systems", *Stockholm International Peace Research Institute (SIPRI),* 2017.: 114.
[15] Feickert, Andrew et al., "U.S. Ground Force Robotics and Autonomous Systems (RAS) and Artificial Intelligence (AI)".: 2.
[16] See Annex for Table 1.
[17] Insaurralde, Carlos and Lane, David. "Metric assessment of autonomous capabilities in unmanned maritime vehicles, Engineering Applications of Artificial Intelligence", Vol. 30, 2014.
[18] See Table 1 in the Appendix for the visualisation of the different classifications of scales of autonomy in military robotic systems.

Military robotic systems

Characteristics of military robotic systems and market size

Military robotic systems merge advances in military tactics, changes in the make-up of the military forces, and innovations through the Fourth Industrial Revolution (4IR).[19] Generally speaking, the 4IR is supported by the revolutionary advance of information technologies and new technologies such as big data, Artificial Intelligence (AI) and robotics that result in increased automation, improved communication and self-monitoring, and the use of smart machines that can analyse and diagnose issues without the need for human intervention.[20] Military robotic systems that armed forces are integrating into their operations are now a force multiplier and are significantly changing the influence of armed forces in the strategic competition of the 21st century.[21] Equal to robots, military robotic systems have (1) sensors to monitor the environment, (2) processors to decide on how to respond to their environment, and (3) capacities to execute a given task.[22] What differentiates military robotics from civilian systems is that their *use* and/or *equipment* is specifically oriented towards military applications. Therefore, a civilian drone, such as a small octocopter becomes a military robotic system once it is used for carrying out reconnaissance mission on a battlefield or for releasing small grenades on enemy forces.[23] While it is difficult to measure the importance that robots will have in the future of conflict, some consider that they will fundamentally change the nature of warfare: *"(…) experts argue that robotics could be the next generation's weapon of mass destruction."*[24]

Platform		2019	2020	2021	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	MALE	2815	3063	3777	4487	5407	6116	6928	17.75%
	HALE	2501	2671	3210	3748	4200	4691	5082	13.75%
	Combat UAVs	1473	1724	2273	2881	3605	4343	5166	24.55%
	Helicopter UAVs	288	367	506	664	863	1070	1308	28.75%
	Small UAVs	928	1029	1321	1622	1962	2285	2631	20.7%
	Loitering UAVs	61	124	179	247	334	430	541	34.35%
	Combat UGVs	4	8	13	26	55	96	156	83%
	IFV UGVs	1	3	6	12	19	29	43	73%

[19] Horowitz, Michael. *Military Robotics, Autonomous Systems, and the Future of Military Effectiveness*, Cambridge University Press, 2017.: 163.
[20] Lee, Min-Hwa et al. "How to Respond to the Fourth Industrial Revolution, or the Second Information Technology Revolution? Dynamic New Combinations between Technology, Market, and Society through Open Innovation ". *Journal of Open Innovation: Technology, Market, and Complexity 4*, Nº 3, 21 June 2018.: 21.
[21] Rossiter, Ash. "The impact of robotics and autonomous systems (RAS) across the conflict spectrum", *Small Wars & Insurgencies*, Vol. 31 Issue 4.: 692.
[22] United States Office of Technical Intelligence, *Office of the Assistant Secretary of Defense for Research and Engineering*, Technical Assessment: Autonomy, 2015.: 2.
[23] Hambling, David. How Ukraine Perfected The Small Anti-Tank Drone, *Forbes*, https://www.forbes.com/sites/davidhambling/2022/06/01/how-ukraine-perfected-the-small-anti-tank-drone/?sh=1bd7808b3171, 1 June 2022. (Accessed on 13.02.2023)
[24] Höpflinger, Markus. "Stand und Entwicklung militärischer Roboter, *Stratos - Militärwissenschaftliche Zeitschrift der Schweizer Armee*, Stratos Digital, 2022.: 1. Translation by the authors.

UGVs	Logistic UGVs	4	6	10	18	29	41	59	57%
	Support UGVs	1	2	3	5	7	10	14	52%
	Combat robots	51	63	89	121	163	204	254	32%
	EOD robots	77	97	141	194	266	347	445	36%
	Transport robots	123	152	211	279	378	478	594	31%
	CBRN robots	68	83	111	147	196	246	304	30%
	Others	26	32	45	60	81	102	127	31%
	Two-legged humanoid bots	0	0.2	0.6	2.3	3.9	6.3	9.6	110%
	Four-legged humanoid bots	0	0.4	0.9	3.5	6.2	9.8	15.1	112%
UMSs	USVs	230	459	617	806	1027	1258	1505	27%
	UUVs	111	297	382	482	613	766	955	26%
Total		**8762**	**10181**	**12896**	**15805**	**19215**	**22528**	**26137**	**20.75%**

Figure 1 - Global Military Robotic and Autonomous System Market (by platform), USD million. [25]

Autonomy in military robotic systems refers to the ability of one or multiple robotic agent(s) to perform a specific task without external supervision.[26] Today, most *"military robotic systems are remotely controlled/piloted or, at the very least, remotely supervised"*, which implies their limits on the autonomy spectrum.[27] Thus, given the cycle of life of weapons systems, military robotic systems are still in the early experimental (entrepreneurial) phase, even if fully autonomous systems already exist.[28] Figure 1 provides an overview of the global military robotics market by system category, and subcategory, along with the size of each market. Forecasts and evaluation of robotics and autonomous systems markets come from a report made by the research company BIS, *Military Robotic and Autonomous (RAS) Systems Market, 2020-2025*, based on primary sources (in-house expertise, interview with industry leaders, etc.) and secondary sources (a host of paid and unpaid databases).[29] A second report, *Military Robotic and Autonomous System (RAS) Market* was used for further predictions on the period 2023-2030.[30]

[25] Figure made by the authors. *Sources*: Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.:95.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.: 74.
[26] Australian Army, Robotic & Autonomous Systems Strategy, *Commonwealth of Australia*, 2018.: 5.
[27] Rossiter, Ash. "The impact of robotics and autonomous systems (RAS) across the conflict spectrum", *Small Wars & Insurgencies*, Vol. 31 Issue 4, 2020a.: 693.
[28] Bunker, Robert. Armed Robotic Systems Emergence: Weapons Systems Life Cycles Analysis and New Strategic Realities, *United States Army War College Press*, 2017.: 4, 50.
[29] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 277-278.
[30] Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.

Typologies and functions of military robotics: UAVs, UGVs and UMSs

Technical advances made in civilian technologies related to 4IR indicate that robotics in the broadest sense is likely to become more accessible to more states around the world.[31] The most prevalent military robotic systems across the world are Unmanned Combat Aerial Vehicles (U(C)AVs).[32] The global size of the UCAV market is reported to be USD 2.881 billion in 2022 and is expected to grow at a compound annual growth of 24.54% a year, reaching 5.166 billion by 2025. Commonly referred to as combat drones, the armed forces use them for a variety of missions, including reconnaissance, intelligence gathering or striking capabilities. Financially, the main market of UAVs is Medium Altitude Long Endurance (MALE) UAVs, which will account for USD 4.486.g billion in 2022 and is projected to reach 6.927.7 billion in 2025. UAVs are the most prominent and currently most advanced military robotic systems, mainly because they have been in use for at least 30 years since the deployment of Pioneer drones by the US Navy during the Second Gulf War in 1990-91.[33]

There are four typologies of military robotics and autonomous systems.[34] These are (1) Unmanned Aerial Vehicles or Systems (UAVs or UASs) which are flying robots[35], (2) ground robots, also known as Unmanned Ground Vehicles (UGVs), (3) maritime robots or Unmanned Maritime Systems (UMSs) that include Unmanned Underwater/Surface Vehicles (UUVs/USVs), and (4) collectively behaving robots, known as robotic swarms.[36] According to findings from 2017, there were at least 381 military robotic systems under development globally.[37] In this study, we will mainly focus on the first three types, as robotic swarms are still a nascent technology with few players working on it. Table 2 present the subcategories of the three main types of military robotics and autonomous systems and provides example each subcategory.

According to the US Congressional Research Service, *"The Department of Defense (DOD) defines UAVs as powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload."*[38] UAVs are the most explored and researched military robotic systems.[39] In particular, research into UAVs have culminated on the question of whether these systems would drive a revolution in military affairs.[40] As of 2019, 95 countries have UAVs in service in their armed forces.[41] Most recently,

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[31] Johnson, James. "The end of military-techno Pax Americana? Washington's strategic responses to Chinese AI-enabled military technology", *The Pacific Review*, Vol. 34 Issue 3, 2021.: 366.
[32] Rossiter, Ash. "The impact of robotics and autonomous systems (RAS) across the conflict spectrum", *Small Wars & Insurgencies*, Vol. 31 Issue, 4, 2020a.: 692.
[33] Coyne, James P. *Airpower in the Gulf*. Arlington, Va: Aerospace Education Foundation, 1992.
[34] *Ibid.:* 169.
[35] The terms unmanned, uncrewed and uninhabited are usually used interchangeably in the literature and are therefore used as synonyms in this study. Overall, they all point out the same idea: no human pilot is aboard. In addition, the term Remotely Piloted Aerial System (RPAS) is oftentimes used, to highlight the idea that a system is not autonomous, but remotely controlled. This is mainly due to ethical reasons.
[36] Sapaty, Sapaty. "Military Robotics: Latest Trends and Spatial Grasp Solutions", *International Journal of Advanced Research in Artificial Intelligence*, Vol. 4 Issue 4, 2015.
[37] Verbruggen, Maaike and Boulanin, Vincent. "Mapping the Development of Autonomy in Weapon Systems", *Stockholm International Peace Research Institute (SIPRI)*, 2017.: 19.
[38] Gertler, Jeremiah. U.S. "Unmanned Aerial Systems", *Congressional Research Service,* No. 7-5700, 2012.: 1.
[39] Rossiter, Ash. "The impact of robotics and autonomous systems (RAS) across the conflict spectrum*", Small Wars & Insurgencies*, Vol. 31 Issue 4, 2020a.: 694.
[40] Chávez, Kerry and Ori Swed, "The proliferation of drones to violent nonstate actors", *Defence Studies*, Vol. 21 Issue 1, 2021.; Horowitz, Michael et al., "Who's prone to drone? A global time-series analysis of armed uninhabited aerial vehicle proliferation", *Conflict Management and Peace Science*, Vol. 39 No. 2, 2022.
[41] Dan Gettinger, "The Drone Databook", *The Center for the Study of the Drone at Bard College*, 2019.: ix.

findings have emphasised that *"Twenty-two countries now possess armed drones and more than 20 others are pursuing this capability."*[42]

There are different types of UAVs that exist: rotary-wing and fixed-wing. The former can have one or more rotors and are easier to take off and land. Fixed-wing UAVs are usually larger and can carry heavier payloads, as well as being able to fly longer and over greater distances.[43] Some experts also differentiate drones by size or weight.[44] In this study, we differentiate them mainly by weight, simplifying NATO's STANAG 4671 to give a clear picture and typology: Class I: from 0 to 150 kg (including microdrones, mini-drones and small drones); Class II: from 150 to 600 kg (tactical drones); and Class III: from 600 kg (including MALE, HALE and armed drones).[45] The global market for UAV was worth USD 8066.5 billion in 2019 and is expected to more than doubled by 2025, reaching USD 21.656.6 billion. According to the UN Institute for Disarmament Research (UNIDIR), the main innovations in the field of UAVs are expected to be (1) morphing/adaptation between rotary-wing and fixed-wing; (2) cross-systems domains, capable of operating on land, in the air and at sea; (3) more efficient batteries and new propulsion technologies; (4) innovative communication systems through 5G and satellite frequency.[46]

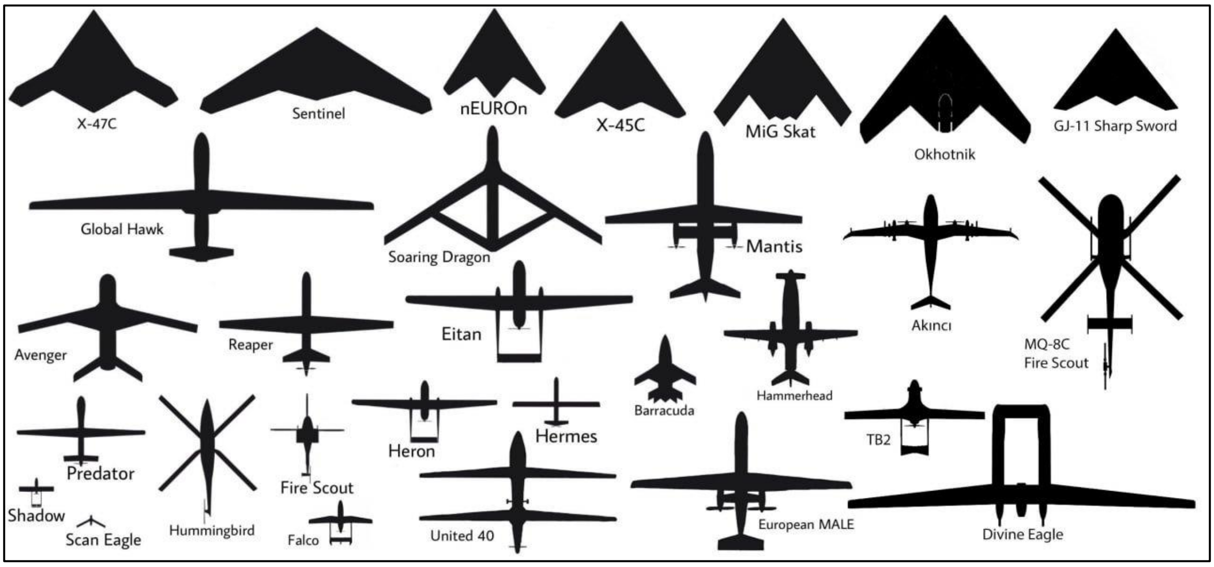

Figure 2 - Shape of the most notable UAVs in the world.[47]

The recent analysis on *Why Drones Have Not Revolutionized War,* using case studies of the drone wars in Libya, Syria, and Nagorno Karabakh, suggests that drones have not yet transfigured military operations to date mainly because they have been designed and used primarily as defence systems.[48] In these three conflicts, although they are very different cases, *"(…) drones did not grant an offensive advantage, they did not strengthen military weaker*

[42] Horowitz, Michael et al., "Who's prone to drone? A global time-series analysis of armed uninhabited aerial vehicle proliferation", *Conflict Management and Peace Science*, Vol. 39 No. 2, 2022.
[43] Grand-clément, Sarah and Bajon, Théo. "Uncrewed Aerial Systems: A Primer", *UNIDIR*, 19 October 2022.: 2.
[44] Despont, Constant et al. "Militärische Drohnennutzung: Erfahrungen, Technologie und Schweizer Optionen". *Center for Security Studies (CSS)*, ETH Zürich, Bulletin 2022 zur Schweizer Sicherheitspolitik.: 34.
[45] NATO STANAG 4671 – Unmanned Aircraft Systems Airworthiness Requirements, Annex A, February 2017, A-5.
[46] *Ibid.:* 5.
[47] Bendett, Samuel. 1/2 An update to the UAV shape/silhouette chart, *Twitter*, https://twitter.com/sambendett/status/1657015915836317696?s=12&t=zPvmk4Pmrfiv-zvkHsyQsw, 12 May 2023. (Accessed on 13.05.2023)
[48] Calcara, Antonio. et al., "Why Drones Have Not Revolutionized War. The Enduring Hinder-Finder Competition in Air Warfare", *International Security*, Vol. 46 No. 4, 2022.: 162.

actors, and they did not cancel close combat."[49] In particular, as illustrated in the Armenia-Azerbaijan conflict, the military infrastructure in which UAVs were integrated provided the Azeris with a strategic advantage over their military opponent.[50] Drones have become "a useful, but not decisive" military tool, meaning that they may help to gain an advantage but do not yet constitute, a decisive advantage themselves.[51] Empirical evidence indeed suggests that in all of the above-mentioned cases, U(C)AVs have not been a game-changer.[52] Indeed, the singular integration of a military robotic system into the armed forces is not sufficient to overcome military structural and conventional inferiority.[53] The ongoing conflict in Ukraine tends to challenge this argument, as better capabilities and uses of UAVs have allowed the Ukrainian armed forces to gain a significant advantage over the Russians in this segment. Cheap drones, used as expendable equipment and therefore subject to high levels of attrition, have been successful in carrying ISTAR, C4 and combat missions.[54]

A UGV or Unmanned Ground Vehicle *is "(…) a mobile ground-based mechanical device that can sense and interact with its environment."*[55] UGVs are becoming increasingly more present in the military field and will undoubtedly become *indispensable "(…) feature[s] of military land operations in the future"*.[56] It is interesting to note that in the field of UGV research and development, it is not only the major powers that are conducting UGV development and testing programmes on UGVs but also countries with less resources.[57] The financial capabilities of many countries, their production readiness and the overlap of expertise and technology with the civilian market (e.g. autonomous car industry, for example), make UGVs more accessible than other types of robots and autonomous systems.[58] Figure 1 shows that, as of 2022, the global market for UGVs accounted for USD 867.7 million, with a large dominance for transport robots, EOD robots and CBRN robots.

This market will grow rapidly, as it is expected that it will reach 2.019. billion in 2025, with the most important growth in combat robots, infantry vehicles and humanoid robots. There are three main types of UGVs: (a) wheeled, (b) tracked, and (c) legged robots. Wheeled UGVs are the most common, as wheels remain the most effective way to travel distances, but they can be limited by extreme terrains (mountains, rocks, etc.). Tracked UGVs are more common with systems carrying a heavier payload and designed to go through difficult environments. However, these systems are also noisier, slower and consume more energy. Legged robots are still rare, but it is a rapidly developing field, as Figure 1 shows a projected growth of more than 110% per year in this domain between 2020-2025.[59] According to UNIDIR, significant innovations in the field of UGV will take place in the following areas: (1) range and type of locomotion types, with new categories, for example a snake-like UGV capable of diving in the

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49 *Ibid.:*155.
50 *Ibid.:* 164-168.
51 Gady, Franz-Stefan. "Useful, but Not Decisive: UAVs in Libya's Civil War", *International Institute for Strategic Studies (IISS)*, 2019.
52 Calcara, Antonio. et al., "Why Drones Have Not Revolutionized War. The Enduring Hinder-Finder Competition in Air Warfare", *International Security*, Vol. 46 No. 4, 2022.: 169.
53 *Ibid.:* 171.
54 Technological Advances Of Uncrewed Systems In The Air, Land And Maritime Domains, *UNIDIR*, https://unidir.org/events/technological-advances-uncrewed-systems-air-land-and-maritime-domains, 19 April 2023. (Accessed on 20.04.2023)
55 Rossiter, Ash. "The impact of robotics and autonomous systems (RAS) across the conflict spectrum", *Small Wars & Insurgencies*, Vol. 31 Issue 4, 2020a.: 853.
56 *Ibid.:* 852.
57 Unmanned Ground Vehicles: Global Developments and Future Battlefield, *Manhoar Parrikan Institute for Defence Studies and Analyses*, https://www.idsa.in/issuebrief/unmanned-ground-vehicles-ssharma-220422, 22 April 2022. (Accessed on 18.08.2022)
58 *Ibid.:* 859.
59 Grand-clément, Sarah and Bajon, Théo. "Uncrewed Ground Systems: A Primer", *UNIDIR*, 19 October 2022.: 2.

sand, (2) improvement of communication capabilities, with optical communication, and (3) improvement of antennas and communication means.[60]

Figure 3- World Large Autonomous Underwater Vehicles (UUVs).[61]

[60] *Ibid.:* 5-6.
[61] Sutton, H I. World Large Submarine Drones Compared, Including Royal Navy Cetus, *Covert Shores*, http://www.hisutton.com/World-Large-XLUUV-Compared.html, 5 December 2022. (Accessed on 23.03.2023)

Unmanned Underwater Vehicles (UUVs) and Unmanned Surface Vehicles (USVs) are the two types of Unmanned Maritime Systems (UMSs or UMVs). UUVs *"(…) are any vehicles that are able to operate underwater without a human occupant."*[62] UUVs are divided into two sub-categories: (a) Autonomous Underwater Vehicles (AUVs) and (2) Remotely Operated Vehicles (ROVs). As shown recently, UUVs are increasingly being used and developed by militaries around the world, and advances in AI and autonomy will be significant.[63] As of today, UUVs account for approximately 20% of all robotic systems under development worldwide. The denomination USVs can also include optionally manned vessels. Figure 1 shows that in 2022, the global UMS market represented USD 1.287 billion, and it is expected to grow to 2.460 billion by 2025.

According to UNIDIR, the main innovations in the field of UMSs will be in: (1) vehicle structure, specifically in biomimicry, to design synthetic products that are modelled on biological systems, (2) advanced materials improving the waterproof capacity of hulls, (3) hydrogen-oxygen fuel cells that increase the autonomy and energy efficiency, (4) hydroacoustic communication, and (5) inertial navigation systems.[64] Developments in AI and communication bandwidth enabling greater autonomy and situational awareness are also particularly important for UMSs.[65] In the future, it is therefore possible to imagine the apparition of long duration UMSs, operating in GNSS-denied environments.[66] Figure 4 below shows the different military and civilian functions of UAVs, UGVs and UMSs.

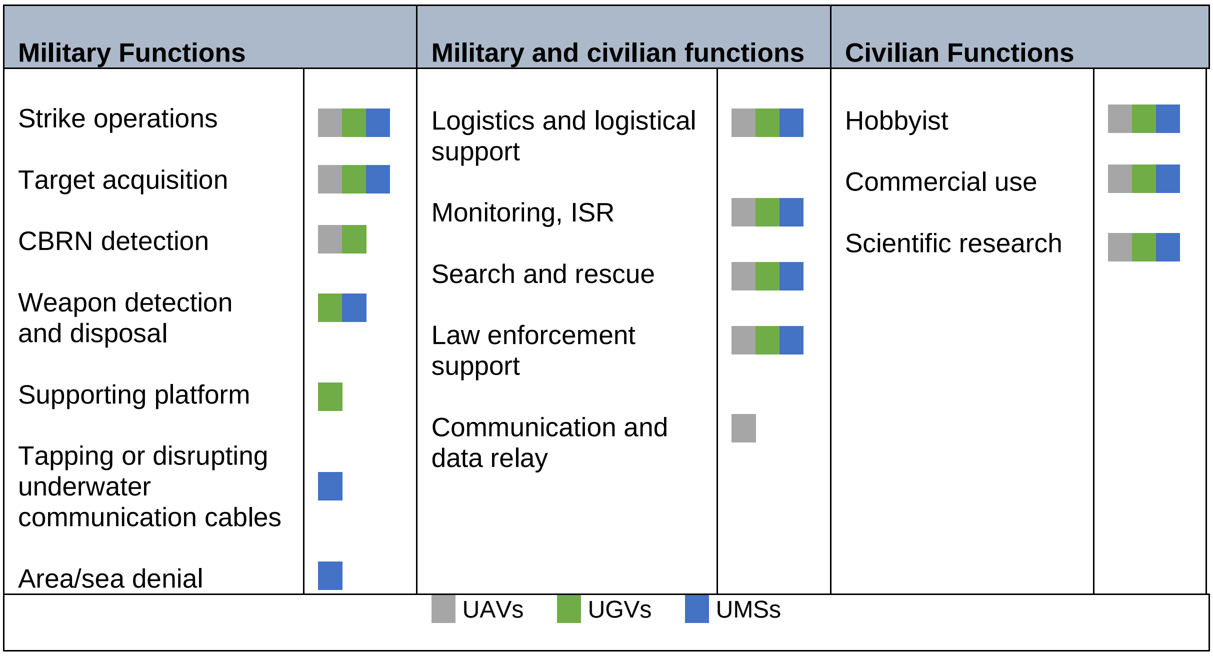

Figure 4 - Functions of UAVs, UGVs and UMSs in the military and civilian domains.[67]

[62] Allard, Yannick and Shahbazian, Elisa. "Unmanned Underwater Vehicle (UUV) Information Study", *Defence Research & Development Canada*, 2014.: 1.
[63] Gafurov, Salimzhan and Klochov, Evgeniy. "Autonomous unmanned underwater vehicles development tendencies", *Procedia Engineering*, Vol. 106, 2015.
[64] Grand-clément, Sarah and Bajon, Théo. "Uncrewed Maritime Systems: A Primer", *UNIDIR*, 19 October 2022.: 5-6.
[65] Technological Advances Of Uncrewed Systems In The Air, Land And Maritime Domains, *UNIDIR*, https://unidir.org/events/technological-advances-uncrewed-systems-air-land-and-maritime-domains, 19 April 2023. (Accessed on 20.04.2023)
[66] Trends 2023-2043 Across the Physical, Biological, and Informational Domains – Volume 2: Analysis, *NATO Science & Technology Organization (STO)*, March 2023.: 48.
[67] Figure made by the authors. *Source*: Grand-clément, Sarah. "Uncrewed Aerial, Ground, and Maritime Systems: A Compendium", *UNIDIR*, March 2023.: 7.

UNIDIR stresses that the concept of swarming is not new.[68] Robotic swarms mimic swarms formed in nature such as bees and ants. Military tactical swarming *"(…) occurs when several units converge to attack a target from multiple axes in a deliberately structured, coordinated way."*[69] Robotic swarms differ from military robotic systems in that they exhibit collective behaviour.[70] Although still a technology in its infancy, robotic swarms have enormous potential because they are cheap and can perform collective behaviour. Most importantly, this technology could complement other existing weapons such as fighter jets or armed UAVs. The Future Combat Air System (FCAS) jet fighter project, for example, is designed as a "system of systems" that intends to team up with drones tasked with performing reconnaissance, intelligence gathering or targeting missions for the main aircraft to facilitate and accomplish the latter's overall mission.[71] The Loyal Wingman project (XQ-58A Valkyrie) is another interesting example where a stealthy and multi-role UAV is designed as a force-multiplier, able to operate alongside a manned aircraft, but able of operating autonomously thanks to its AI capabilities.[72]

Integrating robotic systems into the military has been and will continue to be a challenge – strategically, operationally, tactically and technically. These differences lie in technological advances, operation deployment capabilities and costs, the strategic orientation of the robot(s) and the military planning culture and various innovation as well as defence procurement policies. Figure 5 shows the market share of each type of military robot across the air, ground, and maritime domains.

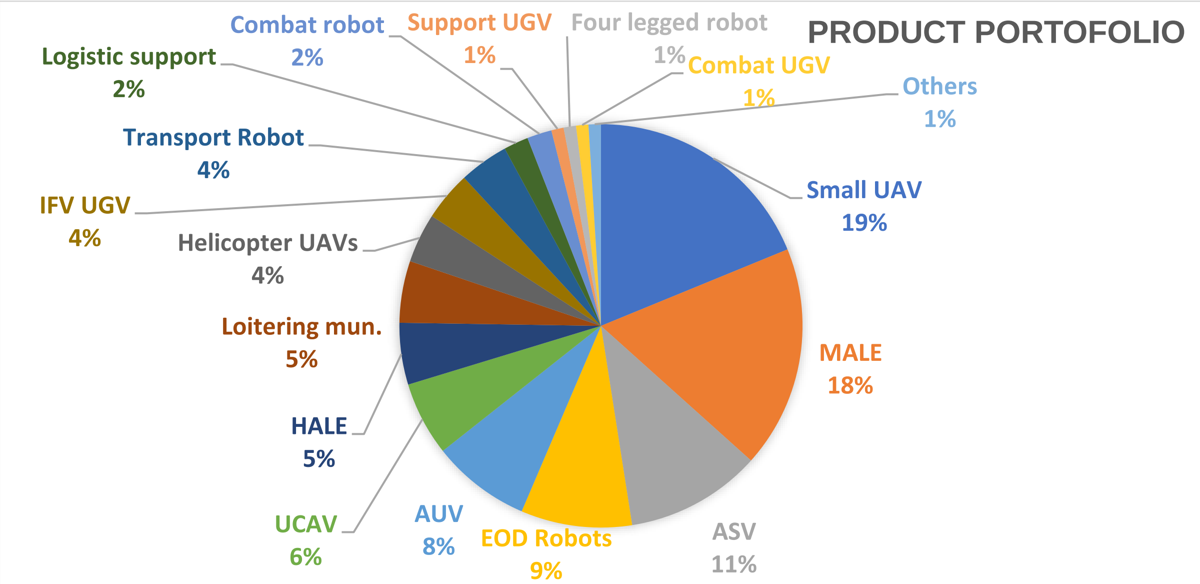

Figure 5 - Global product portfolio share by type of military robots.[73]

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[68] Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR*, 2020.: 23.
[69] *Ibid.*
[70] *Ibid.*: 26.
[71] Reconnaissance and attack: German Bundeswehr is working on drone swarms, *DigitSite36*, https://digit.site36.net/2021/04/19/reconnaissance-and-attack-german-bundeswehr-is-working-on-drone-swarms/, 19 April 2021. (Accessed on 28.08.2022)
[72] Losey, Stephen. How autonomous wingmen will help fighter pilots in the next war, *Defense News*, https://www.defensenews.com/air/2022/02/13/how-autonomous-wingmen-will-help-fighter-pilots-in-the-next-war/, 15 February 2022. (Accessed on 13.02.2023)
[73] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 62.

Congenital themes of (military) robotics

A number of areas influence the development of military robotic systems. Military robotics is a leading area of emerging technologies because it associates highly complex mechanics and equipment with evolving technologies such as AI, including machine learning, computer vision, *etc*.

Sensors, vision, and localisation

Robotic systems are driven by the cycle of sensing, thinking, and acting that allows them to interact with their environment. Sensors (visual, thermal sensors, and electro-magnetic instruments) give robots *"(…) the ability […] to visually perceive the environment."*[74] The vision perceived by the robot's sensors is directly linked to data received and processed by the robot.[75] Robotic perception interprets the sensed data according to temporal variables and the physical environment.[76] This is where intelligence and autonomy are essential, as an "intelligent" robot will be able to understand its context and environment and react autonomously, without the intervention of a human operator. Applied to military robotics, this loop is called the OODA (Observe, Orient, Decide and Act) Weapon System Loop.[77] According to experts, full autonomy is achieved when a weapon system can perform the OODA loop by itself, without any external human intervention. Figure 6 shows the various components of the OODA loop.

Sensing becomes a tool to assess and evaluate the robot's environment, to decide and act accordingly, but it is also used to localise the robot. In particular, *"(…) in applications such as localization, automatic map construction, autonomous navigation, path following, inspection, monitoring and risky situation detection"*, the vision detects features that are used to localise the robot.[78] When it comes to sensing, the camera is a central component of the robot, as it determines the robot's ability to act autonomously in unknown environments.[79] Therefore, as mentioned above, the act of sensing is a *sine qua non* for any robotic system. Any progress in this field are fundamental to the deployment of military robotic systems in armed forces and their operations.

There are three localisation systems in the field of robotic vision: (a) map-based navigation systems, (b) map-building-based navigation systems, and (c) map-free navigation systems.[80] Within these parameters, robotic systems can be reactive or active.

According to experts, full autonomy is attained when a weapon system can perform the OODA loop by itself, without any external human intervention.

[74] Martinez-Gómez, Jesus et al., "A Taxonomy of Vision Systems for Ground Mobile Robots", *International Journal of Advanced Robotic Systems*, Vol. 11 Issue 7, 2014.: 2.
[75] *Ibid.*: 15.
[76] Tawiah, Thomas. "A review of algorithms and techniques for image-based recognition and inference in mobile robotic systems", *International Journal of Advanced Robotic Systems*, Vol. 17 Issue 7, 2020.: 2.
[77] Scharre, Paul. *Army of none: autonomous weapons and the future of war*. First edition. New York ; London: W. W. Norton & Company, 2018.: 43.
[78] Martinez-Gómez, Jesus et al., "A Taxonomy of Vision Systems for Ground Mobile Robots", *International Journal of Advanced Robotic Systems*, Vol. 11 Issue 7, 2014.: 6.
[79] Wu, Jun et al., "Optimized visual recognition algorithm in service robots", *International Journal of Advanced Robotic Systems*, 2020.: 2.
[80] Bonin-Font, Francisco et al., "Visual Navigation for Mobile Robots: A Survey", *Journal of Intelligent and Robotic Systems*, Vol. 53, 2008.: 266.

Reactive robotic systems do not require prior knowledge of the environment, whereas active robotic systems do.[81] Robotic movements and actions are based on their pre-programmed models and on the similarities between the characteristics of the simulation features and reality. Robots thus recognise environmental characteristics, even if they have not yet been deployed yet.[82]

Other types of localisation systems include: (1) odometry, (2) inertial navigation, (3) magnetic compasses, and (4) active beacons.[83] Odometry is relatively simple, provides good short-term accuracy and is inexpensive. It relies on *"(…) the integration of incremental motion information over time."*[84] In the long term, however, odometry is unable to account for small terrain-related errors and is therefore unable to adapt accordingly. Inertial navigation is an old technique based on the use of gyroscopes and accelerometers to measure the rate of rotation and then derive position. While effective, this technique relies too much on constant errors and is not suitable for accurate positioning over a long period of time. Magnetic compasses are a set of sensors that provide an absolute heading measurement and that can solve the navigation needs of autonomous platforms. Their main disadvantage is that they rely entirely on the earth's magnetic field which can be distorted by large steel structures and electric power lines.[85] Active beacons includes trilateration and triangulation, which are the two most commonly used systems for positioning. By communicating with satellites and mapping in near real time, they provide accurate positioning information with minimal processing and small margins of errors. The main problem with this technology is that it involves high acquisition and maintenance costs. Therefore, as it might make sense to use it on a ship or a large aircraft, it will certainly be less interesting in terms of costs to install it on a tiny robotic system.[86]

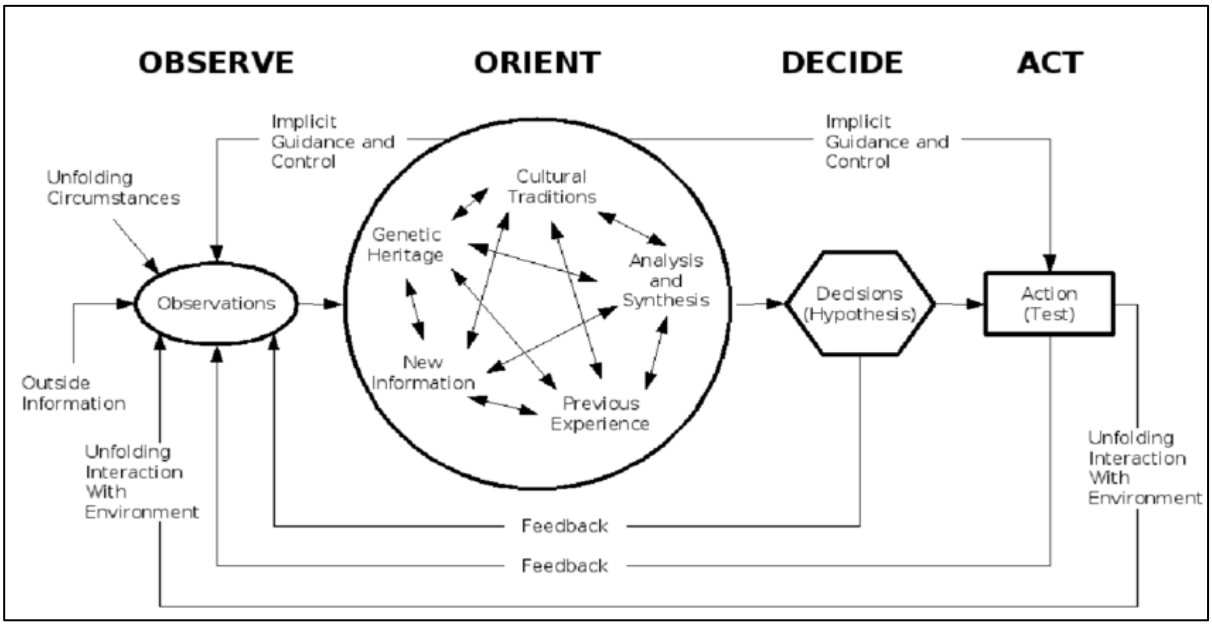

Figure 6 - John Boyd's OODA loop. [87]

[81] *Ibid.:* 279.
[82] *Ibid.:* 283.
[83] Borenstein, Johann et al. "Mobile robot positioning: Sensors and techniques". *Journal of robotic systems*, Vol. 14, No 4.,1997.: 231-249.
[84] *Ibid.:* 234.
[85] *Ibid.:* 238.
[86] Cohen, Charles. and Koss, Frank., 1992, "A Comprehensive Study of Three Object Triangulation." *Proceedings of the 1993 SPIE Conference on Mobile Robots, Boston*, MA, Nov. 18-20.: 95-106.
[87] Frost, Susan et al. "A Briefing on Metrics and Risks for Autonomous Decision-Making in Aerospace Applications." *American Institute of Aeronautics and Astronautics*, 2012.: 4.

In outdoor environments, robots can use Global Positioning System (GPS), which *“(…) could provide satisfactory positioning accuracy for most outdoor location-based service.”*[88] However, not the case when robots are performing indoor tasks. Another issue with the use of GPS in military-related activities is that the entire infrastructure was developed by the US Department of Defense, and the US government deliberately applies small margins of error in timing and satellites to *“(…) prevent a hostile nation from using GPS in support of precision weapons delivery.”*[89] Thus, it would be relatively hasardous for any military other than the US to base entirely its positioning system solely on GPS. However, there exists methods to provide secure GPS positioning, using P-Codes to encrypt sensitive data.[90] In addition, the Communications Security Agreements (COMSEC) are a set of standards and regulations adopted by US government agencies to ensure the authenticity of the information that is transmitted through telecommunications, making of GPS a very powerful technology.[91]

The best-known indoor localisation technique is Simultaneous Localisation And Mapping (SLAM). Robots use this technique to build “*(…) a globally consistent representation of the environment, leveraging both ego-motion measurements and loop closures”*.[92] A distinction must be made between active and passive SLAM. Passive SLAM estimates through its sensors the environment but does not engage actively with it upon detection.[93] Active SLAM is a program that enables robots to decide autonomously about their surroundings and tasks, and to detect and manipulate their environment.[94] SLAM requires a variety of active sensors for the robotic agent(s) to provide the robustness of the data assessment.[95] Whether through SLAM or outdoor robotic sensing, the sensing result is a measurement that enables the robot, or its remote operator, to act according to the mapped result of sensing, localising, and perceiving the environment.[96]

By interacting with its environment, the robot perceives it as a "state space", in which it can change its characteristics.[97] In the state space, the input from the panoramic image for robots *“(…) plays an important role in the object detection and spatial positioning of the robot”*.[98] Alternatively, the environment is perceived as an “across-task variation”, “captured as part of the *context* space”. Under such conditions, *“(…) attributes […] fixed in any specific task” signify to “aid generalization across pairs of tasks.”*[99] Once the robot’s sensors of the robot have made discoveries in their environment, the robot needs to classify the inputs received. A taxonomy for classifying the environment is organised by (1) known classes, (2) known unknown classes,

[88] Cui, Wei et al., “A robust mobile robot indoor positioning system based on Wi-Fi”, *International Journal of Advanced Robotic Systems*, Vol. 17 Issue 1, 2020.: 1.
[89] Borenstein, Johann et al. “Mobile robot positioning: Sensors and techniques”. *Journal of robotic systems*, Vol. 14, No 4.,1997.: 242.
[90] P-Code-Enhanced Encryption-Mode Processing of GPS Signals, *Tech Briefs*, https://www.techbriefs.com/component/content/article/tb/pub/briefs/information-sciences/10271 March 2003. (Accessed on 14.02.2023)
[91] Communications Security (COMSEC), *Office of Security*, https://www.commerce.gov/osy/programs/information-security/communications-security-comsec. (Accessed on 13.02.2023)
[92] Cadena, Cesar et al., “Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust-Perception Age”, *Institute of Electrical and Electronics Engineers (IEEE)*, 2016.: 2.
[93] *Ibid.:* 14.
[94] *Ibid.:* 14.
[95] *Ibid.:* 17.
[96] Tawiah, Thomas. “A review of algorithms and techniques for image-based recognition and inference in mobile robotic systems”, *International Journal of Advanced Robotic Systems*, Vol. 17 Issue 7, 2020.: 3.
[97] Kroemer, Oliver et al., “A Review of Robot Learning for Manipulation: Challenges, Representations, and Algorithms”, *Journal of Machine Learning Research*, Vol. 22, 2021: 10.
[98] Wu, Jun et al., “Optimized visual recognition algorithm in service robots”, *International Journal of Advanced Robotic Systems*, 2020.
[99] Kroemer, Oliver et al., “A Review of Robot Learning for Manipulation: Challenges, Representations, and Algorithms”, *Journal of Machine Learning Research*, Vol. 22, 2021.: 10.

and (3) Unknown unknown classes.[100] This categorisation provides the input for robotic learning and predetermines the behaviour of the robot, depending on the level of intelligence and autonomy that the system enjoys.

Artificial intelligence and robotics

As an evolving and highly complex technology, AI does not yet have a full and comprehensive definition. It can be described as *"(…) the ability of machines to perform tasks that typically require human intelligence – for example, recognising patterns, learning from experience, drawing conclusions, making predictions or taking actions – whether digitally or as the smart software behind autonomous physical system."*[101] AI can be understood as *"(…) the key that can qualitatively enhance the autonomy of robots"*.[102] What AI primarily does is that it facilitates the learning process of robots, using memory mechanisms and the data accumulation to build on its previous experiences and past mistakes or successes. There are different techniques for robots to learn a task. Despite the differences between these techniques, the central characteristic of robotic learning is that access to data is required to visualise, process, and interpret information.[103]

The underlying logic of robotic learning is that *"(…) a machine learns whenever it changes its structure, program, or data (based on its inputs or in response to external information) in such a manner that its expected future performance improves."*[104] There are three types of machine learning: supervised, unsupervised, and reinforcement learning: *"(…) In supervised learning, each example (training sample) consists of a data sample and […] class label. In unsupervised learning, only the data sample from the environment is provided […] without any class label. The learning system is expected to [learn] the underlying data model using data samples and the class labels. In reinforcement learning, the learning system learns from its environment through trial-and-error over time by interacting with the environment."*[105] The objective of robotic learning is to find a control mechanism. Interacting with its immediate environment requires a robot to have *"(…) skill controller that will perform the desired manipulation task."*[106] This allows the robot to optimise its interaction with the environment by making trial-and-error and learning from these mistakes.[107] There are two main kinds of machine learning.

First, Reinforcement Learning (RL) is *"(…) learning of what to do, and how to map situations to actions […] to maximize a numerical reward signal"*.[108] In particular, RL is based on the rate of return of successful robot use. This goal is achieved by continuously repeating tasks until the robot learns them.[109] Thus, RL attempts to autonomously perform tasks in simulation

[100] Sünderhauf, Niko et al., "The limits and potentials of deep learning for robotics", *The International Journal of Robotic Research*, 2018.: 410.
[101] Hunter Christie, Edward. "Defence Cooperation in Artificial Intelligence: Bridging the Transatlantic Gap for a Stronger Europe". *European View* 21, No.1, 2022.: 13.
[102] Kunertova, Dominika. "From Robots to Warbots: Reality Meets Science Fiction", *CSS Analyses in Security Policy*, No. 292, 2021.: 1.
[103] Levine, Sergey et al., "Learning hand-eye coordination for robotic grasping with deep learning and large-scale data collection", *The International Journal of Robotics Research*, Vol. 37 Isues 4-5, 2018.: 435.
[104] Nisson, Nils. "Introduction to Machine Learning: An Early Draft of a Proposed Textbook", *Stanford University Press*, 1998.: 1.
[105] *Ibid.:* 10.
[106] Kroemer, Oliver et al., "A Review of Robot Learning for Manipulation: Challenges, Representations, and Algorithms", *Journal of Machine Learning Research*, Vol. 22, 2021.: 21.
[107] *Ibid.:* 6.
[108] Yang, Ghuang-Zhong et al., "The grand challenges of Science Robotics", *Science Robotics*, Vol. 3 Issue 14, 2018.: 3.
[109] Kober, Jens et al., "Reinforcement learning in robotics: A survey", *The International Journal of Robotics Research*, Vol. 32 Issue 11, 2013.: 1242.

without directly interacting with the environment.[110] This trial-and-error scheme becomes a process of sequences in which robots seek to maximise their optimal task to achieve the required output.[111] However, this type of learning lacks is precisely the possible influence of the robot's interaction with its environment: such as when the environment changes (terrain, environmental conditions, external actors, *etc.*). RL resembles *"(…) a class of learning problems: an agent learns a behaviour through trial-and-error interactions with an environment and by receiving positive and negative feedback for its actions."*[112] There are two categories of RL algorithms: model-based and model-free. On the one hand, model-based RL algorithms are used to provide robots with controls or responses to possible situations they would encounter. On the other hand, model-free RL is learned by interacting with the environment without any inputs from simulations.[113] Because it prepares the robot to learn tasks without interacting with its environment, RL does not teach the robot system adaptability. Therefore, RL does not provide satisfactory results for advanced robotic systems to be used as the leading learning frame.[114] Although RL is undoubtedly a fundamental element of a robot's learning process, it alone is unable to prepare it to evolve in difficult environments where it has to react quickly to unforeseen situations.

Second, Deep Learning (DL) attempts to use data inputs to solve a variety of pre-programmed tasks.[115] DL is *"a generic approach to learning [that] leverages large amounts of data to find a computational solution automatically."*[116] DL refers to the fact that such a process uses multiple layers of Artificial Neural Networks (ANNs) to extract high-level features from the raw data input.[117] As such, DL is probably the learning technique that relies the most on AI to improve the quality of a robot's capabilities. Compared to the other two learning techniques, *"(…) the advantage of deep learning is the ability to learn separable feature representations that are strongly invariant to changing scene conditions."*[118] With this type of learning method, which is more time-consuming and requires more resources, robot systems are on the other hand better prepared to face the dangers of their immediate environment. The advantage of DL over RL and unsupervised learning is that deep neural networks automatically evaluate and select data features according to their properties, thereby providing high results.[119] Consequently, data access provides DL with the tools to robots and their operators with the best possible means of optimising.[120]

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[110] Arulkumaran, Kai et al., "A Brief Survey of Deep Reinforcement Learning", *Institute of Electrical and Electronics Engineers Signal Processing*, 2017.: 1.
[111] Zhang, Tengteng and Hongwei, Mo. "Reinforcement learning for robot research", *International Journal of Advanced Robotic Systems*, 2021.: 3.
[112] Brambilla, Manuele et al., "Swarm robotics: a review from the swarm engineering perspective", *Swarm Intelligence*, Vol. 7, 2013.: 7.
[113] Ibarz, Julian et al., "How to train your robot with deep reinforcement learning: lessons we have learned", *The International Journal of Robotics Research*, Vol. 40 Issue 4-5, 2021.: 699.
[114] Kober, Jens et al., "Reinforcement learning in robotics: A survey", *The International Journal of Robotics Research*, Vol. 32 Issue 11, 2013.: 1266.
[115] Lenz, Ian et al., "Deep learning for detecting robotic grasps", *The International Journal of Robotics Research*, Vol. 34 Issue 4-5, 2014.
[116] Sünderhauf, Niko et al., "The limits and potentials of deep learning for robotics", *The International Journal of Robotic Research*, 2018.
[117] Deng, Li, et Dong Yu. "Deep Learning: Methods and Applications". Microsoft, May 2014.
[118] *Ibid.:* 410.
[119] Arulkumaran, Kai et al., "A Brief Survey of Deep Reinforcement Learning*", Institute of Electrical and Electronics Engineers Signal Processing*, 2017.
[120] Kappler, Daniel et al., "Leveraging Big Data for Grasp Planning", *IEEE International Conference on Robotics and Automation*, 2015.

Swarming and multi-robot coordination

Swarm robotics is a topic that has recently gained prominence and is one of the most important topics in current research.[121] A robotic swarm is an approach to coordinating multiple robots to perform a collective behaviour, taking on the characteristics of swarms found in nature.[122] Experts describe a swarm as a *"(…) group of individual systems that interact and operate as a collective with a common goal. A swarm is a group of systems that operate as a collective."*[123] While swarms are being actively researched, no state is reported to have achieved the integration of a robotic swarm into its military so far.[124] The costs of researching and developing and fielding of robotic swarms remains the main barrier to this technology.[125] These high costs also explain why so few countries around the world have actively launched robotic swarms R&D programmes on.

> *Internal coordination and communication are what define a swarm, and what animals do instinctively is a significant technical challenge for engineers.*

Swarms are *"a large group of locally interacting individuals with common goals."*[126] They act *"(…) like a massive parallel computational system and thus carry out tasks beyond those possible to other type of robotic systems, either complex single robots or centralized groups of robots."*[127] The common denominator of swarms is their collective behaviour, which also must also be coordinated in time and space.[128] Swarm robots are tasked to engage and resolve tasks collectively, thereby avoiding nodal failures.[129] In addition to the three characteristics of robots – sensing, thinking, and acting – the robotic swarm adds another layer by operating *en masse*.[130] In many ways, robotic swarms mimic nature: a school of fish, a flock of birds, and a pack of wolves are all swarms in which the sum of individuals work together to achieve a collective goal. Internal coordination and communication are what defines a swarm, and what animals do instinctively is a significant technical challenge for engineers.[131]

Characteristically, robotic swarms must show (1) robustness, (2) flexibility, (3) scalability and (4) adaptability.[132] Firstly, *"robustness requires that the swarm robotic system should be able to continue to operate, although at a lower performance, despite failures in the individuals, or*

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[121] Yang, Ghuang-Zhong et al., "The grand challenges of Science Robotics", *Science Robotics*, Vol. 3 Issue 14, 2018.
[122] Tan, Ying and Zheng, Zhong-Yang. "Research Advance in Swarm Robotic", *Defence Technology*, Vol. 9 Issue 1, 2013.: 20.
[123] Verbruggen, Maaike. "The Question of Swarms Control: Challenges to ensuring human control over military swarms", *Stockholm International Peace Research Institute (SIPRI),* 2019.: 1-3.
[124] Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR,* 2020.: 53.
[125] *Ibid.*: 54.
[126] Barca, Jan Carlo and Sekercioglu, Ahmed. "Swarm robotics reviewed", *Robotica*, Vol. 31, 2012.: 345.
[127] Boni, Gerado. "From Swarm Intelligence to Swarm Robotics", in Sahin, Erol and William M. Spears (eds.), *Swarm Robotics, Springer*, 2004.: 2.
[128] Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR*, 2020.: 25-26.
[129] *Ibid.*:17; 49.
[130] Otte, Michael. "An emergent group mind across a swarm of robots: Collective cognition and distributed sensing via a shared wireless neural network", *The International Journal of Robotics Research*, Vol. 37 Issue 9, 2018.: 1017.
[131] Verbruggen, Maaike. "The Question of Swarms Control: Challenges to ensuring human control over military swarms", *Stockholm International Peace Research Institute (SIPRI),* 2019.: 3.
[132] Sahin, Erole. "Swarm Robotics: From Sources of Inspiration to Domains of Application", in Sahin, Erol and William M. Spears (eds.), *Swarm Robotics*, Springer, 2004.

disturbances in the environment."[133] Secondly, the flexibility of swarm robotics means that they *"(…) have the flexibility to offer solutions to the tasks at hand by utilizing different coordination strategies in response to the changes in the environment."*[134] The scalability of robotic swarms *"(…) requires that a swarm robotic system should be able to operate under a wide range of group sizes."*[135] Finally, like a pack of wolves, a swarm must be able to adapt changing mission conditions. If a swarm is built around a "leader" and it happens that this leader is eliminated, the other members must be able to adapt, either by de-centralising command or by adopting a new way of behaving.

Monitoring, controlling, and directing a swarm of robots is much more challenging than for individual robots. In fact, they are difficult to operate in practice because of the complexities underlying their nature. It is difficult enough for an operator to get a satisfactory idea of the environment of a single robotic system. But knowing the behaviour, the environment and the state of the swarm in near real time can be almost impossible.[136] Coordinating and controlling the robotic swarm consists of pre-programming the task for each member of the swarm, which logically creates a technical challenge. It is largely because of this technical limitation that well-functioning swarm of military robots is still a distant prospect. However, swarms have enormous potential to improve situational awareness by providing data from multiple perspectives: *"(…) as collaboration is observed and modelled after nature, swarming in nature becomes an invaluable source of knowledge."*[137]

Swarms of robots can be homogeneous or heterogeneous. A homogeneous swarm consists of a group of individuals that all perform the same actions. A heterogeneous swarm, on the other hand, consists of a common collective task set up for the sum of the individuals, but within which each individual performs different actions.[138] Robots in heterogeneous swarms complement each other through their interoperability, flexibility and adaptability.[139] However, unlike to nature, robotic swarms are not without a central actor. So far*, "(…) robot swarms cannot operate without any instructions. They ultimately operate at the direction of human decision makers."*[140] It is therefore likely that autonomy for swarms will be even more difficult to implement for swarms than for other types of robots.

In the absence of such autonomy, human-swarm interaction is seen as an area of research to facilitate the ability of robotic swarms, mainly contributing to the capability of swarms to perform complex tasks.[141] The idea is here to keep humans in the loop in order to promote cooperation between humans and the robots. This human-machine collaboration limits, for the time being, the use of swarms by the armed forces.[142] The integration of robotics into the armed forces also requires new models of decision-making processes.

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[133] *Ibid.:* 10.
[134] *Ibid.:* 11.
[135] *Ibid.*
[136] Roundtree, Karina A., et al. "Transparency: Transitioning From Human–Machine Systems to Human-Swarm Systems". *Journal of Cognitive Engineering and Decision Making*, No.3, September 2019.: 187.
[137] Trends 2023-2043 Across the Physical, Biological, and Informational Domains – Volume 2: Analysis, *NATO Science & technology Organization (STO)*, March 2023.: 47.
[138] *Ibid.:* 1022.
[139] Barca, Jan Carlo and Sekercioglu, Ahmed. "Swarm robotics reviewed", *Robotica,* Vol. 31, 2012.: 346.
[140] Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR*, 2020.
[141] Grosh, John and Goodrich, Michael. "Multi-human Management of Robotic Swarms", in Kurosu, Masaaki (ed.), *HCII 2020: Human-Computer Interaction. Multimodal and Natural Interaction*, 2020.: 603-619.
[142] Warren, Aiden and Hillas, Alek. "Friend or frenemy? The role of trust in human-machine teaming and lethal autonomous weapons systems", *Small Wars and Insurgencies*, Vol. 31 No. 4, 2020.: 823.

Coordination in swarms is the *"(…) mechanism for achieving cooperation."*, either centralised or decentralised.[143] A robot agent leads centralised swarms, like an operator, giving orders to the swarm's members and making tactical decisions. In a decentralised swarm, on the other hand, no robot has authority over others, although sometimes decentralised swarms can have a "leader" or a member that has special prerogatives. Coordination also requires communication between the mass of swarm robots, within the swarm itself. This communication can be either direct or indirect.[144] Indirect communication *"(…) use[s] dynamics of interaction between robots and environment"*, while direct communication consists of intentional communication between robotic agents through sensors.[145] In fact, without coordination and communication between the members of the swarm or its human operator, there is no control, and the mission to complete its task becomes absolutely impossible.[146] This is the reason why swarms are so difficult to handle: a centralised system is great for giving general orders and monitoring an entire group, but it is incapable looking after all the members and analysing all the information coming in from individual robots at the same time; while a decentralised system suffers from the opposite shortcomings.[147] Moreover, integrating swarms of robots into the armed forces is not just a matter of military technology. Instead, it requires the military to adapt its operational structure and doctrine, as well as its tactical and technical procedures.[148]

143 Verma, Janardan and Ranga, Virender. "Multi-Robot Coordination Analysis, Taxonomy, Challenges and Future Scope", *Journal of Intelligent & Robotic Systems*, Vol. 102, 2021.: 5.
144 *Ibid.:* 6.
145 *Ibid.:* 8.
146 Bayindir, Levent. "A review of swarm robotics tasks", *Neurocomputing*, Vol. 172, 2016.: 306.
147 Scharre, Paul. *Army of none: autonomous weapons and the future of war*. First edition. New York; London: W. W. Norton & Company, 2018.: 16.
148 Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR,* 2020.: 56.

Chapter 2: International competition for capabilities in military robotic systems

Recent studies show that military robotic systems have made significant progress worldwide in recent years. Three countries, the United States of America (US), the People's Republic of China (PRC), and the Russian Federation (RF) have received particular attention in the literature on the subject. Evolution in military robotics is both a cause and a consequence of the revived strategic competition between the great powers.[149] The deterioration of relations between the US and Russia; the rapid degradation of political and economic ties between China and the US; and the emergence of a "no limit friendship" between Russia and China are creating a sense of "New Cold War" and a growing dissociation between the collective West and the authoritarian Eurasian regimes.[150]

The United States, China and Russia ranked 1st, 2nd, and 5th in the world in military expenditures in 2022.[151] Compared to other states, they have more financial capacity to invest in military robotic systems. As will be shown, advances in military robotics Research, Development, Test, and Evaluation (RDT&E) rely increasingly on the fusion of military and civilian industries. In particular, because of the dual-use nature of robotics and related technologies, the private sector is more present in this area than in the past. This process – the spin-off of civil technologies for military applications – has already infiltrated the defence industrial base and is influencing current developments in military technologies.[152] *PAX* indicates that various international defence industrial companies are developing military robotics.[153] While many of these companies have primarily developed UAVs, they are also increasingly investing in other unmanned systems.[154]

A recent *PAX* report indicates that *"(…) nearly every country that has a substantial domestic weapon development capability is also adding autonomous functions to its products."*[155] While traditionally only great powers and a handful of highly militarised states (Israel, North Korea, Azerbaijan, etc.) would have access to these military systems, the change and accelerating pace in the international defence industry over the past decade has resulted in the presence of non-traditional large defence players.[156] This new phenomenon of "multipolarisation" of military robotics capability around the world highlights the fact that, while traditional sources of R&D such as the US and Western European states remain dominant, new entrants have gained access to sensitive technologies and are able to establish themselves in this emerging field. Figure 7 shows that the regions with the most important market share in military robotics are North America (45.85%) and Asia-Pacific (31.10%), followed by Europe (17.25%) and the Rest of the world (5.80%). This is rather unsurprising given the US dominance in this field,

[149] Jones, Bruce. "Navigating Great Power Competition – A serious planning start", *Brookings Institution*, https://www.brookings.edu/blog/order-from-chaos/2022/08/03/navigating-great-power-competition-a-serious-planning-start/, 3 August 2022. (Accessed on 01.09.2022)
[150] Brands, Hal and Gaddis, John Lewis. "The New Cold War: America, China, and the Echoes of History", *Foreign Affairs*, https://www.foreignaffairs.com/articles/united-states/2021-10-19/new-cold-war, November/December 2021. (Accessed on 28.08.2022)
[151] Da Silva, Diego Lopes et al., "Trends in World Military Expenditure: 2021", *Stockholm International Peace Research Institute (SIPRI)*, 2022.: 2.
[152] Raska, Michael. "Strategic Competition for Emerging Military Technologies: Comparative Paths and Patterns", *Prism*, Vol. 8 No. 3, 2019.: 67.
[153] Slippery Slope: The arms industry and increasingly autonomous weapons, *PAX*, 2019.: 6-8.
[154] *Ibid.:* 20-29.
[155] Kayser, Increasing Autonomy in Weapons Systems: 10 Examples that can inform thinking, *PAX*, 2021: 2.
[156] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022.

followed by China and, to a certain extent, Russia. Notably, it is the Asia-Pacific market that is expected to grow the most during the 2019-2025 period, by a yearly average (CAGR) of 25.77%.[157]

Still, technology is not the sole vector of military innovation, as history has proven that doctrine, the evolution of strategic, operational and tactical mindsets are imperative to integrate new capabilities and make military thinking evolve.

Considering current and most recent conflicts – from Yemen to Ethiopia and Ukraine – novel entrants into the defence market have provided military robotic systems, primarily UAVs, to warring parties in recent years.[158] These advances in UAV technologies are the face of growing advances in the defence industries of major non-traditional players such as Turkey and its Bayraktar TB2.[159] While UAVs have seen the most rapid development over the past two decades in military robotics, countries are now increasing their RDT&E efforts in other unmanned systems (ground, sea, and surface). Although increasing efforts are made to deploy UGVs, *"(…) none of the systems are fully autonomous or independent task solver."*[160] Similarly, observers have emphasised that for UUVs/USVs, *"(…) the capability for autonomous systems to interpret context and make independent decisions, particularly in a dynamic environment, is not realistic in the short term."*[161] Henceforth, as is shown throughout this chapter, the RDT&E of UUVs/USVs is still at an early stage of development, and *"(…) in their existing, reported form, (…) will not disrupt, but sustain existing concepts of sea control"*.[162]

However, technology is not the only vector of military innovation, as history has shown that doctrine, the evolution of strategic, operational and tactical thinking, is essential to integrate new capabilities and evolve military thinking. Even with cutting-edge technologies, it remains of the highest importance *"(…) how states recruit troops, organize their militaries, plan operations, and strategize."*[163] Yes, technology might be the most visible component of military innovation, *"(…) yet, new technology is rarely the sine qua non of military innovation"*.[164] While scholars have largely neglected the fact that high-tech weapons require high-quality personnel, recent advances in military robotic systems confirm that an overemphasis on new military technologies such as robotics sometimes paints an incomplete picture of the true state of the changing global security landscape.[165]

[157] CAGR is the yearly average variation over a given period of time (in %). If the CAGR of a given market accounts for 25% between 2020 and 2025, it means that during the 2020-2025 period, this market will grow yearly by 25%.
[158] Tavsan, Sinan. Turkish drone success in Ukraine sets stage for Asia roadshow, *Financial Times*, https://www.ft.com/content/03812d1f-6fce-4191-a3c3-0f87afbabc83, 17 March 2022. (Accessed on 12.09.2022)
[159] Jeffrey, James. Has Turkey Become an Armed Drone Superpower, *Australian Strategic Policy Institute (AUSPI),* https://www.aspistrategist.org.au/has-turkey-become-an-armed-drone-superpower/, April 19, 2022. (Accessed on 11.09.2022)
[160] Sanaullah, Muhammad et al., "Land-robot technologies: The integration of cognitive systems in military and defense", *National Defence College E-Journal*, 2022.: 141.
[161] Martin, Bradley et al., "Advancing Autonomous Systems: An Analysis of Current and Future Technology for Unmanned Maritime Vehicles", *RAND Corporation*, 2019.: xi.
[162] Bowers, Ian and Kirchenberger, Sarah. "Not so disruptive after all: The 4IR, navies and the search for sea control", *Journal for Strategic Studies*, Vol. 44 No. 4, 2021.: 621, 633.
[163]. Horowitz, Michael et al., "A Force for the Future. A High-Reward, Low-Risk Approach to AI Military Innovation", *Foreign Affairs*, Vol. 101, No. 3, May/June 2022.: 159.
[164] Ming Cheung, Tai et al., "Frameworks for Analyzing Chinses Defense and Military Innovation" in Ming Cheung, Tai (ed.), *Forging China's Military Might: A New Framework for Assessing Innovation*, 2014.: 23.
[165] Werrell, Kenneth. "Archie to SAM: A Short Operational History of Ground-Based Air Defense", *Air University Press*, 2005.: 174.

Another *PAX* report emphasises that considering the heavy reliance on technological advances based on the private sector, the robotisation of armed forces requires much more openness and cooperation between traditional and non-traditional defence actors.[166] In addition to the traditional military-industrial complex, the architecture of the defence innovation base behind robotic systems increasingly includes research institutions, the private technology sector and a whole range of start-ups and emerging players. Indeed, the vast majority of technologies required to develop military robotics are derived from dual-use expertise. Civilian research and the transfer of technological innovation from the civilian to the military sector rely on existing channels between the sectors and openness to knowledge transfer.[167] This same dynamic can be observed in the United States, China, Russia, and many European countries, even if it takes different forms.

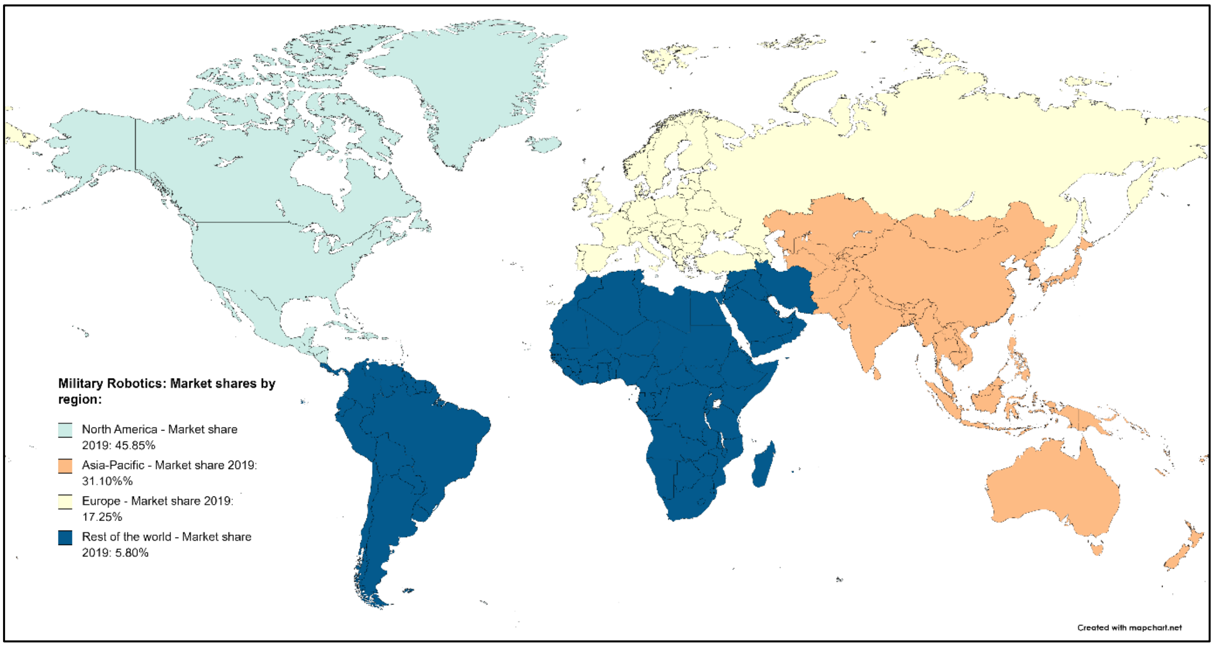

Figure 7 - Global military robotic market by region.[168]

Whereas multiple countries, from the US to Israel and Sweden[169], are advancing their efforts to acquire military robotics capabilities, their different approaches signal that some countries are further ahead than others.[170] In countries such as China and Russia, the governance model and the form of institutions explain the strong emphasis on the centrality of the state and the guidance it provides to support its efforts to develop military robotics. Other countries are characterised by a *laissez-faire* approach, in which investment and intellectual and technical resources come from the private sector and universities, and in which the state provides only loose incentives for innovation.[171] In these countries, defence conglomerates have started to invest independently in technology start-ups and are merging and acquiring

[166] State of AI: Artificial Intelligence, the military and increasing autonomous weapons, *PAX*, 2019.: 5.
[167] Evron, Yoram. “4IR technologies in the Israel Defence Forces: blurring traditional boundaries”, *Journal of Strategic Studies*, Vol. 44 No. 4, 2021.: 581.
[168] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 33.
[169] Petersson, Magnus. “Small states and autonomous systems – the Scandinavian case”, *Journal of Strategic Studies*, Vol. 44 No. 4, 2021.
[170] Haas, Michael. “Projektdokumentation «Robotik in den Streitkräften»” Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022.
[171] Kroenig, Matthew. *The return of great power rivalry: democracy versus autocracy from the ancient world to the U.S. and China*. New York, NY: Oxford University Press, 2020.: 24.

various capabilities that they can deploy in their military robotics RDT&E. Even if states agencies are usually at least indirectly present, these companies have their own agenda and follow their own priorities.

The topic of military robotics is crucial to the fundamental character of defence industries worldwide, as this emerging field is likely to partly modify their structure and orientation. For obvious reasons, defence industries and programmes are fields where secrecy is of strategic importance.[172] Although literature on this topic is relatively abundant, data and factual evidence are hard to find. Furthermore, *"(…) military signalling is also likely to be more effective during peacetime competition, in the sense that the information conveyed has a greater chance of securing political benefits relative to alternatives."*[173] Indeed, the US and China may be more interested in signalling their current and forthcoming military robotic capabilities to make it clear to allies and enemies alike that they are leading the robotic race. Such a phenomenon is supported by some statement by policymakers, such as when former US Deputy Secretary of Defence Robert Work said: *"We will reveal to deter and conceal for warfighting advantage."*[174] In the current geopolitical situation, this logic works both ways: increasing rivalry clearly encourages states, especially the major powers, to keep their innovations and capabilities secret, but careful and targeted disclosure of technological breakthroughs can also be a demonstration of strength that acts as a deterrent.[175]

Military robotic systems undoubtedly have the potential to *"(…) be a significant source of uncertainty."*[176] However, the popular view and media coverage of this field is probably overly focused on "killer robots" and Lethal Autonomous Weapon Systems (LAWS). Most military robotic systems will be unarmed and perform non-lethal tasks such as logistics, transport or Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR), all of which are central to the conduct of military affairs.[177] A recent report from the *Hague Centre for Strategic Studies* states that out of a pool of 696 military robots identified worldwide, only 65 (or 9.33%) are purely lethal systems.[178]

This chapter aims to identify the trends and technologies that the US, China and Russia are prioritising in their defence and security strategies. To this end, the chapter draws on documents, analyses and reports from official government agencies, universities and research institutes, and evaluates existing academic literature. The first three subsections of this chapter highlight the capabilities and intentions of the United States, China and Russia. Emphasis is placed on the differences and similarities identified between them, painting a broad picture of what this global competition will look like and what it means for the international order. The final section of this chapter consists of a brief analysis of three regional powers that have made significant progress in developing military robotics over the past decade: Israel, Australia and Turkey.It highlights the fact that ambitions to field military robotic systems are not limited to the great powers with implications for Switzerland and other states.

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[172] Green, Brendan and Austin Long. "Conceal or Reveal? Managing Clandestine Military Capabilities in Peacetime Competition", *International Security*, 2020.: 48.
[173] *Ibid.:* 57.
[174] Remarks by Defense Deputy Secretary Robert Work at the CNAS Inaugural National Security Forum, *Center for New American* Security (CNAS), https://www.cnas.org/publications/transcript/remarks-by-defense-deputy-secretary-robert-work-at-the-cnas-inaugural-national-security-forum, 2015. (Accessed on 04.08.2022)
[175] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022: Factsheet US: 4.
[176] Montgomery, Evan. "Signals of strength: Capability demonstrations and perceptions of military power", *Journal of Strategic Studies*, 2020.: 321.
[177] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS),* November 2022.: 9.
[178] *Ibid.:* 9

The American way: Leadership by maintaining the military edge

The US approach to defence-related innovation

US defence R&D spendings have been constantly above USD 55 billion since 1983.[179] According to MIT's Lab for Innovation Science and Policy, the Department of Defense (DoD) received USD 90 billion for RDT&E in Financial Year (FY) 2019.[180] Science and Technology (S&T) provides the closest indication of actual spending on defence-related innovation for the defence innovation ecosystem that makes up the efforts to orchestrate overall innovation activities. During FY2021 it received USD 14.1 billion in R&D, representing almost 2% of the total DoD budget for this year.[181] While it is clear that not all of this funding will go to military robotic systems, it is a clear indication of the importance placed in the US on government-led support for defence innovation. More recently, the US has increasingly relied on private sector entrepreneurship to advance dual-use 4IR technologies.

While the situation in the US might seem ideal on paper, the *US National Security Commission on Artificial Intelligence* stressed through its bipartisan report in 2021 that *"(…) America is not prepared to defend or compete in the AI era."*[182] Indeed, some experts argue that in the US system, defence innovation and defence procurement have a deep structural dysconnectivity.[183] This means that while the US defence budget remains huge and unparalleled in the world, government policy tends to focus on short to medium term equipment procurement rather than the long term effort of developing innovation and capabilities (i.e Ground Combat Vehicle programme, cancelled in 2014).[184] Strategically, China's emergence as a military peer or near-peer competitor to the US is a major challenge, creating both a new incentive to innovate and a new urgency to invest: *"The Soviet Union could match the U.S. missile-for-missile but not byte-for-byte. China thinks it can do both."*[185]

The US still upholds the most developed defence innovation base, which comprises *"(…) a wide-ranging variety of research and innovation facilities, with varying degrees of centralisation and embeddedness within the Department of Defense ecosystem."*[186] Six state agencies orchestrate the innovation in the military field. Also, the US Military Academy at West Point has a Robotics Research Center, which is currently working on fifteen distinct robotic projects.[187] The Defense Advanced Research Projects Agency (DARPA), the Defense Innovation Unit (DIU), and the Defense Innovation Board (DIB) are the most important actors

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179 Gholz, Eugene and Sapolsky, Harvey. "The defense innovation machine: Why the U.S. will remain on the cutting edge", *Journal of Strategic Studies*, 2021.: 859.
180 Budden, Phil and Murray, Murray. "Defense Innovation Report: Applying MIT's Innovation Ecosystem & Stakeholder Approach to Innovation in Defense on a Country-by-Country Basis", *MIT Lab for Innovation Science and Policy*, 2019.: 11.
181 Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, Program Acquisition Cost by Weapon System, United States Department of Defense Fiscal Year 2021 Budget Request, *US Department of Defense, 2022*, Chapter 4.: 12.
182 Schmidt, Eric and Work, Robert. "Final Report, National Security Commission on Artificial Intelligence", 2021.: 1.
183 Flagg, Melissa and Corrigan, Jack. "Ending Innovation Tourism. Rethinking the U.S. Military's Approach to Emerging Technology Adoption", *Center for Security and Emerging Technology (CSET)*, 2021.: 1.
184 The US Army's armoured vehicle conundrum, *Army technology*, https://www.army-technology.com/features/featurethe-us-armys-armoured-vehicle-conundrum-4369690/, 10 September 2014. (Accessed on 12.05.2023)
185 Miller, Chris. *Chip War: The Fight for the World's Most Critical Technology*. First Scribner hardcover edition. New York: Scribner, an imprint of Simon & Schuster, 2022.: 284.
186 Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies (IISS)*, 2021.: 20.
187 United States Military Academy West Point, *Robotics Research Center*, https://www.westpoint.edu/centers-and-research/robotics-research-center/research. (Accessed on 22.08.2022)

in R&D for military innovation in the US. Interestingly, both China and Russia have attempted to copy DARPA in their efforts to modernise their national defence innovation base, highlighting the relative success of the institution as an incubator and developer of innovative military technologies.[188] While the functioning of the US defence innovation base aimed for large technological domination *vis-à-vis* its competitors, it has been argued that the current form of engagement with commercial companies, which are supposed to drive defence innovation in 4IR, resembles *"(…) a practice more akin to innovation in tourism rather than bona fide strategy for bringing in cutting-edge technology into the DOD"*.[189]

While it is true that Washington's adversaries, especially Beijing, have closed the gap in terms of military R&D expenditures, the US still dominates these fields by an important margin.

Since the end of the Cold War, there have been significant changes in the US defence innovation base, with R&D receiving less attention in annual budgets than before, despite an increasing defence budget. In addition, the bureaucratic complexities associated with defence acquisitions cause significant slowdowns in the adaptation of technologies from the civilian to the military sector.[190] According to a recent report from the Center for Security and Emergent Technology (CSET), the Pentagon's efforts to advance innovation in defence are chaotic, with at least 28 *"(…) different DOD organizations dedicated to building business relationships between the military and private sector innovators."*[191] Recent efforts to build a bridge between the Pentagon and tech entrepreneurs, particularly in Silicon Valley, have met with limited success.[192] US policymakers have realised that the US military dominance in technology increasingly depends on commercial technologies developed primarily for commercial uses and that this could represent a weakness in the future.[193] To respond to this challenge, former Secretary of Defense Ash Carter decided in 2015 to set up the DIU to build bridges between commercial companies, start-ups and the DoD. The main added value of DIU is that it is a relatively small and flexible institution that can *"(…) strengthen existing relationships and build new ones; help scout for new technologies; and help function as a local interface (…)"* between DoD and the private innovation sector.[194]

The International Institute for Strategic Studies (IISS) stresses that the US has focused its defence innovation base and capabilities on exploiting the potential of emerging technologies to become force multipliers in direct competition with rivals.[195] Therefore, in Washington's

[188] Andrew Lewis, James. "Linking National Security and Innovation: Part 1", *Center for International and Strategic Studies (CSIS)*, 2021.: 3-4.
[189] Flagg, Melissa and Corrigan, Jack. "Ending Innovation Tourism. Rethinking the U.S. Military's Approach to Emerging Technology Adoption", *Center for Security and Emerging Technology (CSET)*, 2021.: 7.
[190] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022: Factsheet US.: 2-3.
[191] Flagg, Melissa and Corrigan, Jack. "Ending Innovation Tourism. Rethinking the U.S. Military's Approach to Emerging Technology Adoption", *Center for Security and Emerging Technology (CSET)*, 2021.: 6.
[192] Blank, Steve. As Silicon Valley Tries to Enlist, the Pentagon Strangles Innovation, *War on the Rocks,* https://warontherocks.com/2022/04/as-silicon-valley-tries-to-enlist-the-pentagon-strangles-innovation/, 2022. (Accessed on 19.08.2022)
[193] Sargent, John F. and Gallo, Marcy. "The Global Research and Development Landscape and Implications for the Department of Defense", *Congressional Research Service*, June 28, 2021.: 6.
[194] Remarks of Secretary of Defense Ash Carter at Stanford University, "Rewiring the Pentagon: Charting a New Path on Innovation and Cybersecurity," *Defense.gov*, https://www.defense.gov/News/Speeches/Speech-View/Article/606666/drell-lecture-rewiring-the-pentagon-charting-a-new-path-on-innovation-and-cyber/, April 23, 2015. (Accessed on 23.08.2022)
[195] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies (IISS)*, 2021.: 12.

view, the US must do everything it can to prevent China or any other country from overtaking US supremacy in war-fighting capabilities and technological progress. US policymakers also recognise that American dominance in technology – military and civilian – has fueled the country's economic growth since the end of the Second World War and allowed it to shape the international order largely in its interests.[196] There are therefore strong economic and geopolitical incentives for the US government to develop ambitious military innovations to outspend and outcompete its competitors, as it was the case when President Reagan and Secretary of Defense Weinberger launched the Strategic Defense Initiative (SDI) in 1983.[197] While it is true that Washington's adversaries, especially Beijing, have closed the gap in terms of military R&D expenditures, the US still dominates these fields by an important margin: "*For comparison, the much-hyped Chinese defense budget (not the Chinese defense R&D budget) did not exceed the level of U.S. defense R&D spending until the late-2000s. Cumulative Chinese defense R&D investment is therefore quite modest compared to cumulative U.S. defense R&D investment.*"[198]

US capabilities in R&D of military robotic platforms[199]

Over the past two decades, the US has increasingly deployed military robotic systems in combat situations. As Peter Singer acknowledged*: "When U.S. forces went into Iraq, the original invasion had no robotic systems on the ground. By the end of 2004, there were 150 robots on the ground in Iraq; a year later, there were 2,400; by the end of 2008, there were about 12,000 robots of nearly two dozen varieties operating (…) in Iraq. As one retired Army officer put it, the "Army of the Grand Robotic" is taking shape."*[200] The US defence innovation base has been active in the field of military robotic systems, and recent figures for FY2023 illustrate so. While not making explicit requests for funding to be received on military robotic systems, the DoD requested FY2023 of USD 3.1 billion for UAVs and USD 338.7 million for USVs. These figures are illustrative of the DoD's investment scale in military robotics.[201] Figure 8 below shows that in 2019, the overall procurement budget of the US armed forces robotic systems accounted for USD 7.522 billion, with half of it (3.712) solely for UAS. Importantly, if one adds up the R&D of each type of system, it results that USD 3.253 billion was invested in R&D of military robotics in 2019 (with a large majority in UAS).

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[196] Sargent, John F. and Gallo, Marcy. "The Global Research and Development Landscape and Implications for the Department of Defense", *Congressional Research Service*, June 28, 2021.: 19.
[197] Brands, Hal. *The Twilight Struggle: What the Cold War teaches us about great-power rivalry today*. New Haven: Yale University Press, 2022.: 169.
[198] Gholz, Eugene and Sapolsky, Harvey. "The defense innovation machine: Why the U.S. will remain on the cutting edge", *Journal of Strategic Studies*, 2021.: 859.
[199] A list of military robotic systems in service by the US armed forces can be found in the Appendix (Table 3).
[200] Singer, Peter. Military Robots and the Laws of War, *Brookings*, https://www.brookings.edu/articles/wired-for-war-robots-and-military-doctrine/, 22 January 2009. (Accessed on 07.08.2022)
[201] In comparison, the former US administration adopted H.R.5515 - John S. McCain National Defense Authorization Act for Fiscal Year 2019, authorizing the US DoD to spend USD 9.6 billion on unmanned vehicle systems.

Platforms		USD million in 2019	Units of equipment
UAVs	Procurement	3712	-
	R&D	2140	-
	In construction	198	-
	Existing UAV units	-	3250
UGVs	Procurement	86	-
	R&D	343	-
	Existing UGV units	-	134
UMSs	Procurement	212	-
	R&D	770	-
	UMS units	-	61
Total		**7461**	**3445**

Figure 8 - Procurement, RDT&E and unit types of robotic systems in the US.[202]

Additionally, according to the Robotics Branch Chief of the US Army, the US had 22 programs on military robotics (currently in an initial phase, in development, or production) as of 2019.[203] According to the robotics portfolio funding, the US Army has invested gradually more in modernising its robotic equipment between 2014 (USD 14 million) and 2020 (USD 317 million).[204] This goes along a growing list of US armed forces publications illuminating the importance of the military robotics field for the future development of the military.[205]

US doctrine developments in military robotics

The US government believes that the use of military robotic systems in combat provides military advantages at the strategic, operational, tactical and technical levels. Strategically and operationally, the pursuit of advanced military robotics capabilities strengthens the US claim to global military primacy and acts as a deterrent to its adversaries. Tactically, US armed forces employ military robotic systems when *"(…) missions might tax the physical endurance of onboard human operators, or missions that pose a high risk of injury, death, or capture of onboard human operators – so-called "three-D" missions, meaning missions that are dull, dirty, or dangerous."*[206] This military perspective was embraced by the Obama administration, as it

[202] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 144.
[203] Hatfield, Stuart. "Army Robotic and Autonomous Systems (RAS) Modernization Portfolio", *US Army*, 2019.: 3.
[204] *Ibid.:* 4.
[205] These documents are a) Unmanned Systems Integrated Roadmap, 2017-2042, *US Department of Defense*, 2017.; b) Army Science Board, Robotic and Autonomous Systems of Systems Architecture, 2016.; c) Andresk, Nikolai and Henderson, James. "Operationalizing Robotic and Autonomous Systems in Support of Multi-Domain Operations White Paper", *Army Capabilities Integration Center*, 2018, d) Zacharias, Greg. "Autonomous Horizons. The Way Forward, United States Air Force", *Air University Press*, 2019, and e) United State Air Force, Science and Technology Strategy, 2019.
[206] O'Rourke, Ronald. "Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress", *Congressional Research Service*, 2022.: 1.

increased the use of drone strikes in dangerous theatres of operation (Pakistan, Somalia, Yemen, etc.)[207] The US military doctrine has not yet fully provided answers to integrating robotics into armed operations. While DoD *Directive 3000.09* provides the strategic provisions for deploying UAVs, it is not comprehensive in theory, authority, and culture, which are all central aspects of military doctrine.[208] This document states that all autonomous systems powered by AI must be accountable to five principles: (1) Responsibility; (2) Equitability; (3) Traceability; (4) Reliability; and (5) Governability. In 2017, the US Army released a report named *The US Army Robotic and Autonomy Systems Strategy* that provides guidelines for the integration of robotic and autonomous systems within the armed forces.[209] This administrative document identifies four priority areas for the integration of robotic and autonomous systems: (1) Forward tactical presence for reconnaissance and increasing situational awareness; (2) To carry transport and logistic tasks to lighten the soldiers' physical and cognitive workloads; (3) To prepare and facilitate movement and manoeuvre and; (4) To be used in the first line to protect the human force.[210]

Adjusting doctrines and tactics is a long process that requires training and flexibility, and that can benefit greatly from After Action Reviews (AAR). The Marine Corps is advancing quickly in this direction, as *The Force Design 2030* highlights that the Marine Corps Warfighting Laboratory (MCWL) will be used to improve the formation to the use of new technologies in combat: "*Reserve Marines in grades sergeant through colonel will be assigned to this unit on the basis of their expertise in areas like artificial intelligence, data science, human systems, advanced manufacturing, quantum computing, autonomy/robotics, space, supply chain management, cyber, synthetic biology, energy and materials sciences, and other technology fields."*[211] Moreover, because the US military is characterised by a joint and integrated component at most levels of the force, the challenge of integrating new types of equipment is even greater than it would be for other militaries.[212] Nevertheless, it has been pointed out that *"(…) the U.S. military is adapting its doctrine to the evolving nature of the battlefield. For example, the Marine Corps is including an assistant squad leader technology operator in the squad"*, requiring coordination between traditional force deployment and unmanned systems.[213] The US has a longstanding tradition of keeping the human on the loop when it comes to the lethal use of force, *"But that policy does allow exception, so it's more of a preference than a hard rule."*[214] Figure 9 below indicates the size of the US market in UAVs, UGVs and UMSs.

[207] Zenko, Micah. "Obama's Final Drone Strike", *Council on Foreign Relations (CFR)*, https://www.cfr.org/blog/obamas-final-drone-strike-data, 20 January 2017. (Accessed on 07.08.2022)
[208] Directive Number 3000.09, *Department of Defense*, https://media.defense.gov/2023/Jan/25/2003149928/-1/-1/0/DOD-DIRECTIVE-3000.09-AUTONOMY-IN-WEAPON-SYSTEMS.PDF, 2023. (Accessed on 26.01.2023)
[209] The US Army Robotic and Autonomy Systems Strategy, *Department of Defense*, April 2017.
[210] *Ibid.*: 1.
[211] Force Design 2030 – Annual Update, United States Marine Corps (USMC), *Department of the Navy*, May 2022.: 2.
[212] Osborn, Kris. Joint Warfare: How the U.S. Military Would Win a War Against Russia or China, *The National Interest,* https://nationalinterest.org/blog/buzz/joint-warfare-how-us-military-would-win-war-against-russia-or-china-174564, 16 December 2020. (Accessed on 02.11.2022)
[213] Viscuso, Sebastian. Unmanned Systems and the Future of War, *National Defense*, https://www.nationaldefensemagazine.org/articles/2021/5/28/unmanned-systems-and-the-future-of-war, 28 May 2021. (Accessed on 25.08.2022)
[214] Howe, Elizabeth. The Army's Big Convention Was Full of Armed Robots, *Defense One*, https://www.defenseone.com/technology/2022/10/armys-big-convention-was-full-armed-robots/378435/, 13 October 2022. (Accessed on 14.10.2022)

Platforms	2019	2020	2021	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	3712	4175	5043	5999	7128	8260	9481	17.8%
UGVs	86	114	152	196	253	314	385	27.5%
UMSs	212	576	676	781	901	1013	1127	14.4%
Total	**4010**	**4865**	**5871**	**6976**	**8282**	**9587**	**10993**	**17.7%**

Figure 9 - US military robotic and autonomous systems market, USD million.[215]

The US can be considered the world leader when it comes to R&D, fielding and integration of military robotic systems into its armed forces.[216] Table 3 in the Appendix details the various military robotic systems currently in use or under development in the United States. It was the first country to use UAVs in combat, with the development of the MQ-1 Predator in 1996 and its use during the Second Gulf War, leading some experts to speak of a "Revolution in Military Affairs" (RMA).[217] A recent report by the US Congressional Research Service highlights that at least twenty-six types of UAVs are in use by the US armed forces, making the US military the world's leader in unmanned systems.[218] The main US industrial producers of UAVs are world leaders, with companies such as Lockheed Martin, Boeing, Northrop Grumman and General Atomics. Thus, in terms of current R&D capabilities to develop UAVs, the US has institutional strengths through the presence of traditional defence innovation actors and strong financial support from the government.[219] The US also gains from a longstanding experience in developing, producing, using and improving these systems, which provides an advantage over Russia and China. The size of the US market in UAVs has no equivalent in the world, as it accounted for USD 3.712 billion in 2019 and is expected to grow to 9.481 billion by 2025, with a CAGR of 17.83%. This figure is explained by the fact that the US armed forces have been using UAVs for three decades and that the American industry sells these systems to at least 40 countries worldwide.[220] The US UAV market is much larger than China's and Russia's, which are respectively projected to reach USD 4.213 and 1.004 billion by 2025 (see next two sections).

The US is using its Army Research Lab as a steering instrument to increase the effectiveness of human-robot interaction, with the aim of deploying intelligent and complementary human-machine teams.[221] In this regard, the development of UGVs is challenging because it implies

[215] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 151.
[216] Bergen, Peter et al. World of Drones, *New America*, https://www.newamerica.org/international-security/reports/world-drones/, 30 July 2020. (Accessed on 25.08.2022)
[217] Tilford, Earl. "The Revolution in Military Affairs: Prospects and Cautions". *Strategic Studies Institute*, US Army War College, 1995.
[218]*Ibid.*: 5.
[219] Office of the Under Secretary of Defense, Program Acquisition Cost by Weapon System, *US Department of Defense*, 2022: xiii.
[220] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 155
[221] Hambling, David. "The US Army is creating robots that can follow orders", *MIT Technology Review*, 2019.

the integration of combat tactics into the robots' hardware. Therefore, the US Army invests significant resources to develop *"(…) a novel computational model that allows robots to be more effective teammates in tactical environments."*[222] US developments in this field include the US Army Robotic Combat Vehicles (RCV) program, the RCV-light and the RCV-medium UGV programs.[223] Besides, the US Army and Marine Corps are also procured with foreign types of UGVs, such as Milrem's THeMIS and Rheinmetall's Mission Master.[224] The American UGV market is set to grow from USD 85.8 in 2019 to 384.7 million in 2025 at a CAGR of 27.47%, which represent the highest increase among all types of unmanned systems.

At sea, the US is investing in the whole spectrum of UMS capabilities: from the Sandshark man-portable Battlespace Awareness UUV to the XLUUV Future Capabilities, a vehicle able to carry huge payloads as well as strike capabilities.[225] As the US pushes for a closer security coalition in the Indo-Pacific with its traditional allies such as the UK, Japan and Australia, it is pursuing several projects to advance capabilities in the field of UUVs and USVs.[226] Generally, the US' focus on UUVs is representative of its "Third Offset Strategy", *"(…) devised to maintain U.S. military superiority over possible future adversaries such as China and Russia in a cost effective way"*.[227] The best example of this emerging strategy is the "Sea Hunter", an unmanned autonomous ship expected to revolutionise antisubmarine warfare at minimal costs, by *"(…) making the ocean transparent"*.[228] The UMS market is predicted to grow from USD 212.1 million to 1.126 billion by 2025.

Over the past decade, there has been a growing interest in military swarms of robots within the US defence establishment. Today, the US is by far the world leader in this field. In 2017, the DoD tested its Perdix robotic swarm, which was launched from an F/A-18 Super Hornet. The DoD, in collaboration with the Massachusetts Institute of Technology, successfully developed this technology, which consists of a swarm of 103 small and interchangeable drones that can communicate with each other without the intervention of a human operator.[229] The DoD released a press statement announcing that *"the micro-drones* [of the Perdix swarm] *demonstrated advanced swarm behaviors such as collective decision-making, adaptive formation flying, and self-healing."*[230] According to a report by UNIDIR*, "the US Army Research Laboratory's DCIST research alliance also creates autonomous swarms for a wide range of missions in dynamically changing, harsh and contested environments, including search and rescue of hostages and information gathering after terrorist attacks or natural disasters."*[231]

[222] "Army Research Enables Robots to Learn New Concepts", *US Army Combat Capabilities Development Command Army Research Laboratory*, 2021.
[223] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 141
[224] Ball, Mike. Milrem Robotics Unveils Entry for US Army UGV Program, *Unmanned Systems Technology,* https://www.unmannedsystemstechnology.com/2021/06/milrem-robotics-unveils-entry-for-us-army-ugv-program/, 21 September 2021. (Accessed 02.12.2022)
[225] Reddie, Andrew and Goldblum, Bethany. Unmanned Underwater Vehicles (UUV) Systems for Submarine Detection, *CSIS*, https://ontheradar.csis.org/issue-briefs/unmanned-underwater-vehicle-uuv-systems-for-submarine-detection-a-technology-primer/, 29 July 2019. (Accessed on 05.09.2022)
[226] Department of the Navy, Campaign Framework, 2021: 16.
[227] Gady, Franz-Stefan. World's Largest Anti-Submarine Robot Ship Joins US Navy, *The Diplomat*, https://thediplomat.com/2018/02/worlds-largest-anti-submarine-robot-ship-joins-us-navy/, 6 February 2018. (Accessed on 08.09.2022)
[228] Wong, Yuna Huh et al. "Deterrence in the Age of Thinking Machines", *RAND Corporation*, 2020.: 89.
[229] Yoma, Yulius. US DoD successfully tests micro-drone Perdix, *Aerotime Hub*, https://www.aerotime.aero/articles/16486-us-dod-successfully-tests-micro-drone-perdix, 10 January 2017. (Accessed on 06.09.2022)
[230] Department of Defense Announces Successful Micro-Drone Demonstration, *US Department of Defense*, https://tinyurl.com/ykbwkuu6, 9 January 2017. (Accessed on 12.05.2023)
[231] Ekelhof, Merel and Paoli, Persi. "Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems", *UNIDIR*, 2020.: 50.

The use of swarms is significant because it allows the US armed forces to perform sensitive missions with low-cost capabilities that would otherwise require the use of much more expensive equipment. The US armed forces are working closely with research institutions and the private sector to research and develop robotic swarms.[232] The DoD is funding research programmes to develop support systems to enhance the coordination and control capabilities of swarms of robots. They are actively pushing the defence innovation base to accelerate their R&D efforts to test and later field robotic swarms. The work of the DCIST thus illustrates the close alignment and collaboration between key players across the defence innovation base, from both the civilian and military sectors.

In summary, the US is the forerunner in the development, production and deployment of military robotics. It is, and is likely to remain, the dominant player in the field. But the overarching military dominance it enjoyed in the immediate aftermath of the Cold War may be coming to an end. The world order is likely to enter a phase of US primacy diluted by China's catch-up in most military metrics, including robotics. The sheer size of the US military budget, the intensity of its dual-use and military-oriented R&D, and the interpenetration between the branches of the DoD and its network of universities and technological institutes – the best in the world – place it well in the military robotics race. Another advantage the US has over its competitors is its network of military and political alliances with some of the world's most advanced and wealthy countries, which typically involve cooperation in R&D and the sharing of key technologies. The US has formal alliances with countries such as Japan, South Korea, Australia and NATO members, and informal partnerships with states such as Taiwan and India, which provide a strategic advantage.[233] However, Washington's main comparative strength – its open, free and liberal environment – can also be a weakness in certain circumstances. In this context, the United States has accused Beijing, and to a lesser extent Moscow, of espionage and theft of property. As FBI Director Christopher Wray put it bluntly: *"There is no country that presents a broader, more severe threat to our innovation, our ideas and our economic security than China does."*[234] To respond to this challenge, the US government has sought to counter China's state-led efforts to steal sensitive technology by targeting Chinese private companies, third parties, or academics working in America. This has become the FBI's top counterintelligence priority, and it appears that this policy has had some success, despite the exodus of Chinese entrepreneurs, scientists and academics from the US since 2020.[235]

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[232] Park, Steven. "Smarter Robot Swarms Could Change Warfare", *Association of the United States Army*, 2021.
[233] Major Non-Nato Ally, *Wikipedia*, https://en.wikipedia. https://en.wikipedia.org/wiki/Major_non-NATO_allyorg/wiki/Major_non-NATO_ally. (Accessed on 02.12.2022)
[234] Williams, Pete. FBI Director Wray says scale of Chinese spying in the U.S. "blew me away", *NBC News*, https://www.nbcnews.com/politics/politics-news/fbi-director-wray-says-scale-chinese-spying-us-blew-away-rcna14369, 2 February 2022. (Accessed on 06.09.2022)
[235] Kuang, Wing. Australia and the US are cracking down on 'Chinese spies' in STEM, and Beijing is taking advantage, *ABC News*, https://www.abc.net.au/news/2023-02-10/australia-loses-young-scientists-as-china-recruit-stem-talents/101926524, 9 February 2023. (Accessed on 13.02.2023)

China's catch-up game: Military build-up and fusion of the civilian-military spheres

China's approach to military innovation

For the last decade, the PRC accelerated the integration of different actors as part of the defence innovation base, making significant advances in military robotics. This is primarily the result of the Military-Civil Fusion (MCF) or *Yumin Ronghe*, which was proposed in China's 13th Five-Year Plan (FYP) for Defence Science, Technology, and Industry Development in 2016.[236] Since the introduction of the MCF, any progress in civil or military innovation in China has been directly or indirectly guided by the leadership of the Chinese Communist Party (CCP). It has been argued that *"By virtue of this, the Chinese political leadership plays a disproportionate role in steering defence-innovation plans at the expense of bottom-up innovation efforts."*[237] Key to the MCF is the recognition by the Chinese leadership that cutting-edge technology and its translation into military applications require close cooperation between military and civilian actors.[238] This strategy aims at acquiring *"(…) better, cheaper, and faster"* military systems for the Chinese armed forces.[239] China's MCF could be described as *"(…) a nationwide endeavour that seeks to 'fuse'* [China's] *economic and social development strategies with its security strategies to build an integrated national strategic system and capabilities in support of China's national rejuvenation goals."*[240] This strategy also aims to reduce the burden of military spending and development costs on the Chinese economy.[241]

The MCF was deliberately designed as a tool to enable China to catch up with more advanced countries in terms of civil and military industrial bases, such as the US, Japan, France, the UK and Israel.[242] Xi Jinping has made the MCF one of his top national security priorities, as evidenced by his personal chairmanship of the Commission for Integrated Military and Civilian Development (CIMCD). Overall, MCF can be seen as part of China's 'Long Game', which consists of three successive phases: (1) blunting US hegemony in the Indo-Pacific; (2) building a world-class military to win wars; and (3) entering the world stage and asserting its global strategic ambitions.[243] Yet, MCF has had mixed results: *"China has developed pockets of economic excellence. It leads the world in some manufacturing industries – especially in the production of household appliances, textiles, steels, solar panels, and simple drones – because low wages and generous government subsidies enable its companies to churn out inexpensive goods."*[244]

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[236] "Military-Civil Fusion and the People's Republic of China", *United States Department of State*, 2020.
[237] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies (IISS),* 2021.: 17.
[238] Ming Cheung, Tai and Hagt, Eric. "China's Efforts in Civil-Military Integration, Its Impact on the Development of China's Acquisition System, and Implications for the United States", *Naval Postgraduate School*, 2019.
[239] *Ibid.:* 163.
[240] China Power Project, How developed is China's defense industry?, *CSIS*, https://chinapower.csis.org/arms-companies/, (Accessed on 30.08.2022)
[241] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022: Factsheet PRC.: 2-3.
[242] Raska, Michael. "Strategic Competition for Emerging Military Technologies: Comparative Paths and Patterns." *PRISM*, vol. 8, no. 3, 2019, 64–81.: 71.
[243] Doshi, Rush. *The Long Game: China's Grand Strategy to Displace American Order.* S.I. Oxford University Press, US, 2023.
[244] Beckley, Michael, and Brands, Hal. *Danger Zone: The Coming Conflict with China*. First edition. New York, NY: W.W. Norton & Company, 2022.: 46.

China's significant investments in 4IR technologies are also reflective of its evolving military doctrine, that not only aims at deterring US capabilities but at the implementation of what experts have called Forward Defence (FD), relying on the transformation of the PLA into a world-class military.

A conglomeration of actors composes the Chinese defence-relation innovation architecture: the armed forces, state-owned enterprises, the Chinese Academy of Science (CAS), research institutes, private corporations, and defence conglomerates.[245] As these actors are all directly or indirectly linked to the Central Military Commission (CMC) and the CIMCD, the term "private actors" in the Chinese context needs to be critically assessed. The modernisation of the People's Liberation Army (PLA) therefore relies on inputs from the "private sector", which seeks to accelerate the production of dual-use capabilities for the armed forces, while ultimately being managed by the highest echelons of the CCP and, in most cases, Xi Jinping himself.[246] As recently reported by the RAND Corporation, the desire to foster an entrepreneurial defence innovation base is at odds with the control that the CCP requires in overseeing private sector R&D. It is said that innovation does not fare particularly well under strict top-down management.[247]

Since 2019, the Chinese military leadership has been preparing to approach an *"(…) intelligentized warfare"* era.[248] The Chinese predict that AI and military robotic systems, along with other EDTs such as quantum computing and biotechnologies, will characterise this new style of warfare and gradually replace the role of the soldier in the armed forces.[249] In this regard, China released an ambitious *New Generation Artificial Intelligence Development Plan* in 2017 envisioning Beijing's global lead in AI technologies by 2030.[250] Therefore, according to Brookings, the Chinese military has been *"(…) pursuing significant investments in robotics, swarming, and other applications of AI and machine learning."*[251] According to a 2018 report published by the US DIU, China would be systematically engaged in the acquisition of cutting-edge military technology through theft of foreign property, reverse engineering and espionage.[252]

This effort is part of a larger policy from the Chinese leadership – called "Made in China 2025" – to catch up with the West in the most sensitive advanced technologies such as 5/6G and semiconductors. In this domain, for example, *"China's problem isn't only in chip fabrication. In nearly every step of the process of producing semiconductors, China is staggeringly dependent on foreign technology, almost all of which is controlled by China's geopolitical rivals*

[245] Weinbaum, Cortney et al., "Assessing Systemic Strengths and Vulnerabilities of China's Defense Industrial Base", *RAND Corporation*, 2022.: 75.
[246] Office of the Secretary of Defense, Annual Report to Congress: Military and Security Developments Involving the People's Republic of China, 2021.: 147.
[247] Weinbaum, Cortney et al., "Assessing Systemic Strengths and Vulnerabilities of China's Defense Industrial Base", *RAND Corporation*, 2022.: 3.
[248] Kania, Elsa. "AI Weapons" in Chinese Military Innovation, *Brookings Institution*, 2020.: 1.
[249] Fedasiuk, Ryan et al., "Harnessing Lightning. How the Chinese Military is Adopting Artificial Intelligence", *Center for Security and Emerging Technologies (CSET)*, 2021.: iii.
[250] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 40.
[251] Kania, Elsa. "AI Weapons in Chinese Military Innovation", *Brookings Institution*, 2020.: 1.
[252] "China's Technology Transfer Strategy: How Chinese Investments in Emerging Technologies Enable a Strategic Competitor to Access the Crown Jewels of U.S Innovation", *US Department of Defense, Defense Innovation Unit Experimental*, 2018.

– Taiwan, Japan, South Korea, or the United States."[253] The growing geopolitical competition between China and the US over the past decade has increased the strategic implications of prioritising innovation in military robotic systems and AI.[254] China is investing and betting on the integration of robotic systems into the armed forces to achieve its goal of unsettling its main global competitor, the US, by 2049.[255] According to a recent article in Foreign Affairs, *"Over the last few years, China has invested roughly the same amount as the United States has in AI research and development, but it is more aggressively integrating the technology into its military strategy, planning, and systems."*[256] This context pushes the PLA to *"(…) catch up with and passing the United States and Russia by metaphorically turning more tightly in corners as trends in science and technology change direction"*.[257]

China's doctrine developments in military robotics

China's significant investment in 4IR technologies also reflects its evolving military doctrine, which aims not only to deter US capabilities, but also to implement what experts call Forward Defence (FD), based on the transformation of the PLA into a world-class military.[258] Interestingly, Xi has also invested in orienting China's foreign policy, security and defence expertise by studying Western military thinking, and is increasingly using academic institutions and think tanks to inform the PLA's future doctrines and force structures. Recent findings highlight that *"the PLA has reorganized a key military think tank – the Academy of Military Science (AMS)—and reasserted this organization's leadership of military science research programs. The revamped AMS is tasked with driving defense innovation and ensuring that the PLA's warfighting theory and doctrine fully capitalize on disruptive technologies like AI and autonomous systems."*[259] According to RAND, the Chinese military is rapidly adapting its doctrine to EDTs, recognising that AI has a fundamental role to play in developing future combat operations and exploiting the PLA's capabilities.[260] Automation stands at the forefront of Chinese efforts to adapt its military theory, doctrine, and force structure to the requirements of war in the 21st century: *"(…) China is mainly focused on using AI technology to make rapid and more well-informed choices, as well as on designing a variety of autonomous military systems."*[261]

According to testimony at a hearing of the US-China Economic and Security Commission, the Chinese focus on military robotic systems dates back to the 1980s and has only accelerated

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[253] Miller, Chris. *Chip War: The Fight for the World's Most Critical Technology*. First Scribner hardcover edition. New York: Scribner, an imprint of Simon & Schuster, 2022.: 249.
[254] Kania, Elsa. "AI Weapons" in Chinese Military Innovation, *Brookings Institution*, 2020.: 539.
[255] Xi's Vow of World Dominance by 2049 Sends Chill Through Markets, *Reuters*, https://www.bloomberg.com/news/articles/2022-10-26/xi-s-vow-of-world-dominance-by-2049-sends-chill-through-markets#xj4y7vzkg, 26 October 2022. (Accessed on 12.05.2023)
[256] Horowitz, Michael et al., "A Force for the Future. A High-Reward, Low-Risk Approach to AI Military Innovation", *Foreign Affairs*, Vol. 101 No. 3, May/June 2022.: 159.
[257] Dahm, Michael. "Chinese Debates on the Military Utility of Artificial Intelligence", *War on the Rocks*, https://warontherocks.com/2020/06/chinese-debates-on-the-military-utility-of-artificial-intelligence/, 5 June 2020. (Accessed on 03.09.2022)
[258] Doshi, Rush. *The Long Game: China's Grand Strategy to Displace American Order.* S.I. Oxford University Press, US, 2023.: 292.
[259] Office of the Secretary of Defense, Annual Report to Congress: Military and Security Developments Involving the People's Republic of China, 2021.: 148.
[260] Burke, Edmund et al., "People's Liberation Army Operational Concepts", *RAND Corporation*, 2020.: 22.
[261] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 40

since then.[262] A report in 2016 stressed that *"(…) China's investments into unmanned systems are considerable and will likely yield larger numbers of increasingly capable platforms."*[263] Robotics and unmanned systems are seen as a benchmark for China's military deployment of information technology platforms and the establishment of a US-style "system of systems" structure capable of conducting a joint and integrated operational approach.[264] This integration may be an ongoing process, as the media has reported several instances of Chinese-made drones or robots being used for policing or military operations: for example, during the Shanghai lockdown in May 2022, robot dogs were seen carrying loudspeakers that broadcast safety information to citizens.[265] Because of China's top-down government structure, there is limited access to open and reliable information that reveals the details of Chinese defence innovation to conduct military robotics R&D. These difficulties in assessing China's capabilities and investments in its military-industrial complex are well known and are a recurring problem for analysts of China's defence developments.[266]

China's capabilities in R&D of military robotic platforms[267]

China's military R&D spending was estimated as between USD 27 and USD 44 billion in 2018.[268] A recent analysis by CSET noted that "*China spent no more than about (…) $2.7 billion on AI-related defense* [comprising robotics and autonomous systems] *R&D in 2018 – and possibly much less, depending on how much of the unattributed S&T* [science and technology] *spending went to defense projects."*[269] This figure focuses on projects that are strictly for military systems, but dual-use projects may be partly related to military applications. The available data allow only an approximation that China spends a few billion dollars per year on R&D of AI and robotics systems, of which USD 2.7 is believed to be strictly for defence applications.[270] Based on these estimations, China spends much more than Russia (USD 63 million in 2018) and is on course to spend close to what DARPA is receiving in funding for its R&D (USD 3.5 billion in 2018).[271] Important to note also is the preeminent character of autonomy and robotics among China's AI R&D projects: "*Of the 343 AI equipment contracts, 35 percent are related to intelligent or autonomous vehicles."*[272]

China's most significant military robotics advance is its fleet of UAVs. Since the early 2000s, China has become *"(…) a driving force of the horizontal and vertical proliferation of military*

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[262] Kania, Elsa. "Testimony before the U.S.-China Economic and Security Review Commission Hearing on Trade, Technology, and Military-Civil Fusion, Chinese Military Innovation in Artificial Intelligence", *Centre for New American Security (CNAS)*, 2019.: 9.
[263] Ray, Jonathan et al., "China's Industrial and Military Robotics Development", *U.S.-China Economic and Security Review Commission*, 2016.: 62.
[264] Rudd, Kevin. *The Avoidable War: The Dangers of a Catastrophic Conflict between the US and XI Jinping's China*. New York: Public Affairs, 2022.: 156.
[265] Pollpeter, Kevin and Kerrigan, Amanda., "The China AI and Autonomy Report"*, Center for Naval Analyses (CNA),* Issue 21, August 25, 2022.
[266] Tian, Nan and Su, Fei. "A New Estimate of China's Military Expenditure", *Stockholm International Peace Research Institute (SIPRI),* 2021.
[267] A list of military robotic systems in service by the Chinese People's Liberation Army can be found in the Appendix (Table 4).
[268] Acharya, Ashwin and Arnold, Zachary. "Chinese Public AI R&D Spending", *Center for Security and Emerging Technology (CSET)*, 2019.: 12-13.
[269] *Ibid.*
[270] *Ibid.*: 14.
[271] Defense Advanced Research Projects Agency (DARPA) – Budget, *DARPA*, https://www.darpa.mil/about-us/budget, (Accessed on 31.08.2022)
[272] Fediasuk, Ryan et al., "Harnessing Lightening: How the Chinese military is Adopting Artificial Intelligence", *Center for Security and Emerging Technology (CSET)*, 2021.: 15.

UAVs".[273] Beijing has indeed made remarkable advances since unveiling its Wing Loong-1 UCAV in 2009.[274] The Wing Loong has notably become a popular choice among middle-eastern countries, first and foremost because of its availability and relatively low costs.[275] According to SIPRI's Arms Transfer Database, China will export UAVs to at least sixteen countries between 2009 and 2021, including Pakistan, Egypt and Saudi Arabia.[276] Figure 11 shows that the UAV market is largely dominant as compared to other types of military robotics in China. It already weighed almost USD 1.3 billion in 2019 and will reach USD 4.2 billion by 2025.

China's innovation in the UAV market is robust due to continuous military and financial support from the state. To achieve its goal of becoming a leader in UAV R&D, and in the spirit of its MCF completion strategy, China has established a subsidiary of the Aviation Industry Corporation of China called AVIC Unmanned Aerial Vehicle Systems.[277] China is creating capabilities to develop a more diverse and technologically advanced UAV fleet, which was recently exposed at the Zhuhai Air Show in September 2021.[278] China currently has seven combat UAV systems in production and it does not hesitate to show off its new capabilities: *"During the PRC's 70th anniversary parade, PLA displayed several advanced unmanned aerial systems such as the rocket-powered, high-speed Wuzhen-8 and the Gongji-11 stealth unmanned combat aerial vehicle."*[279] China is currently developing or producing several additional types of UAVs.[280] As a result, China has acquired extensive R&D capabilities to develop UAVs, accumulated experience in using these systems and working with partners, and gained access to valuable AAR from its customers who have used these systems in conflicts.[281] Therefore, China has become one of the leading nations in the field of UAVs, especially in the relatively low cost and mid-range systems. Figure 10 shows that China is the driving force of military robotic production and procurement in the Asia-Pacific region – excluding the US – with a total market at least three times larger than its nearest competitor, India.

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[273] Hwang, Wonjune. "Development of Peoples' Republic of China's Unmanned Aerial Vehicles (UAVs) and Its Impact on the East China Sea", *International Journal of China Studies*, 2020.: 122.
[274] Fediasuk, Ryan et al., "Harnessing Lightening: How the Chinese military is Adopting Artificial Intelligence", *Center for Security and Emerging Technology (CSET)*, 2021.: 15.
[275] Herlevi, April. China as a Niche Arms Exporter, *Center for Naval Analyses (CAN)*, https://www.cna.org/our-media/indepth/2021/08/china-as-a-niche-arms-exporter, August 31, 2021. (Accessed on 31.08.2022).
[276] Stockholm International Peace Research Institute, Trade Register Arms Transfer Database 2021, *SIPRI*, https://armstrade.sipri.org/armstrade/page/trade_register.php. (Accessed on 12.09.2022)
[277] Chandra, Atul. "Why China's armed UAVs are a global export success, and its fighter jets, not so much," *Defence Procurement International*, https://www.defenceprocurementinternational.com/features/air/china-has-disrupted-the-military-drone-market, 5 November 2021. (Accessed on 10.09.2022)
[278] "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China", *Office of the Secretary of Defense*, 2021.: 57.
[279] *Ibid.*
[280] Yeo, Mike. Chinese airshow offers glimpse at military's new drones, *DefenseNews*, https://www.defensenews.com/unmanned/2021/09/30/chinese-airshow-offers-glimpse-at-militarys-new-drones/, 30 September 2021. (Accessed on 25.09.2022)
[281] Hwang, Wonjune. "Development of Peoples' Republic of China's Unmanned Aerial Vehicles (UAVs) and Its Impact on the East China Sea", *International Journal of China Studies*, 2020.: 129.

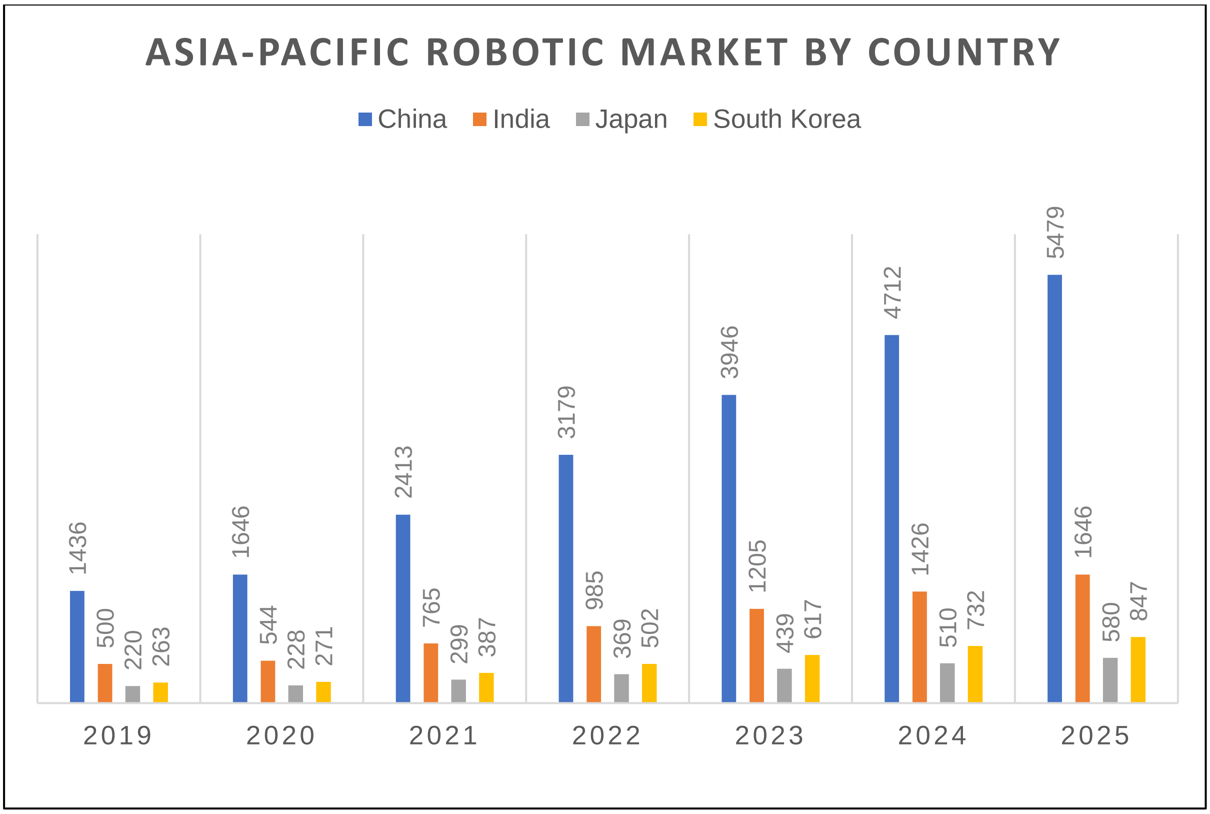

Figure 10 - Asia-Pacific robotic and autonomous systems market by country, USD million.[282]

Chinese defence innovation efforts are expanding in all domains of military robotics – air, ground, surface, and undersea.[283] As the US DoD assesses: *"The PLA considers unmanned systems to be critical intelligentized technologies, and is pursuing greater autonomy for unmanned aerial, surface, and underwater vehicles to enable manned and unmanned hybrid formations, swarm attacks, optimized logistic support, and disaggregated ISR, among other capabilities."*[284] While China does not currently have the highest levels of sophistication in UGV systems, their development is supported through *"(…) government programs* [of] *numerous universities, companies, and research institutes".*[285] Notably, *"Compared with the rapid development of ground unmanned combat platform in recent years* [particularly from Russia and the US], *the development of the ground unmanned combat platform in China is relatively slow."*[286]

Of the few UGV robotic systems that China has tested in recent years, most have been limited to reconnaissance missions. The main exception is the integration into infantry units of NORINCO's Sharp Claw I in 2020, a small remote-controlled UGV carrying a light machine

[282] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 178.
[283] Kania, Elsa. "Testimony before the U.S.-China Economic and Security Review Commission Hearing on Trade, Technology, and Military-Civil Fusion, Chinese Military Innovation in Artificial Intelligence", *Centre for New American Security (CNAS)*, 2019.: 11.
[284] "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China", *Office of the Secretary of Defense*, 2021.: 89.
[285] Ray, Jonathan et al., "China's Industrial and Military Robotics Development", *US-China Economic and Security Review*, 2016.: 62.
[286] Wang, H.B. et al., "The development status and trends of ground unmanned combat platforms", *Journal of Physics: Conference Series*, 2021.: 7.

gun.[287] In November 2018, the PRC reportedly began testing old Type 59 tanks that had been converted into improvised unmanned prototypes. These tests were apparently conducted to practice an unmanned minesweeper, as well as transforming stored Type 59s into unmanned reconnaissance or patrol vehicles.[288] As shown in Figure 11, the Chinese UGV market was small in 2019, with a value of USD 28.7 million. However, it is the area that will see the highest growth, with a CAGR of 63.78% between 2020 and 2025, to reach USD 465.7 million. When China's UGV market reaches this figure, it will surpass the US market to become the largest in the world.

Because of the growing militarisation of the South and East China Seas, China's leadership is committed to accelerate the development of UMSs. This dynamic is a corollary to China's doctrinal shift and is *"(…) the next step in the evolution of the PLA away from its historical preoccupation with internal security and China's continental defense to an emerging doctrine of deploying military power beyond China's shores."*[289] In this context, China has planned to deploy its first indigenously produced UUV, the HSU001 large displacement vehicle, to support PLA Navy operations.[290] The PLA considers that UUVs have the ability to act as a force-multiplier and enhance its ability to project power.[291] China lags behind America's most advanced programmes such as Seahunter or Orca – the Extra Large UUVs (XLUUV), expected to conduct tasks such as mine countermeasures, anti-submarine warfare, anti-surface warfare, electronic warfare and strike missions – and likely to become the US Navy's crown jewels.[292] Yet, PLA's classified programme named "912 Project" aims at developing a fully autonomous AI-driven UUV to handle surveillance, mine laying and attack missions.[293] China's UMS market is set to grow sevenfold between 2019 and 2025, from USD 114.9 million to USD 799.9 million. Given China's strong maritime build-up over the past decade – making the PLN the world's first navy in terms of surface combatants – and its investment in USVs/UUVs, China will in many ways soon become a leader in UUVs. Figure 10 shows the importance of China's military robotics within the Asia-Pacific region (52.7% of the market) and the speed of Chinese growth in this area compared to other regional powers such as India, Japan and South Korea. China's military robotics build-up is unmatched in the Asia-Pacific region. Table 4 provides a detailed list of military robotic systems in use and under development in China.

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[287] Ju, Juan. Norinco's Sharp Claw I UGV in service with Chinese army, *Janes*, https://www.janes.com/defence-news/news-detail/norincos-sharp-claw-i-ugv-in-service-with-chinese-army, 15 April 2020. (Accessed on 26.09.2022)

[288] A New Use for the Type 59 Tanks: Unmanned Combat Vehicles, *IMedia*, https://min.news/en/military/de10cc0e4281005995f4b7fa37badcf2.html, 13 October 2020. (Accessed on 31.08.2022)

[289] Rudd, Kevin. *The Avoidable War: The Dangers of a Catastrophic Conflict between the US and XI Jinping's China*. New York: Public Affairs, 2022.: 156.

[290] Goldstein, Lyle. "China's Unmanned Underwater Vehicles: How They Will Dominate Undersea Combat", *The National Interest*, 2022.

[291] Fedasiuk, Ryan. "Leviathan Wakes: China's Growing Fleet of Autonomous Underwater Vehicles*", Center for International Maritime Security*, 2021.

[292] Werner, Ben. Navy Awards Boeing $43 Million to Build Four Orca XLUUVs, *USNI News*, https://news.usni.org/2019/02/13/41119, February 13, 2019. (Accessed on 31.08.2022)

[293] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 183.

Platforms	2019	2020	2021	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	1293	1469	2093	2679	3228	3740	4213	23.5%
UGVs	29	40	87	154	240	343	466	63.78%
UMSs	115	138	233	346	478	630	799	42.05%
Total	**1437**	**1647**	**2413**	**3179**	**3946**	**4713**	**5478**	**17.7%**

Figure 11 - China military robotic and autonomous systems market, USD million.[294]

Overall, given the global economic situation and the stress caused by Russia's invasion of Ukraine, China may also feel the effects of the international sanctions regime imposed on Russia by Western countries. While China is not directly sanctioned, it relies on imports of weapons systems, particularly from Moscow, and the indirect impact on its defence industry is significant.[295] The current situation of the global order will convince even more Xi Jinping and the CCP that it is a necessity for China to build a resilient and reliable domestic defence innovation base to procure its armed forces.[296] China is still far from self-sufficient in sensitive supply chains that are key to the military industry and software development, especially in microchips. It therefore relies on imports from US allies and partners such as South Korea and Taiwan, making it vulnerable to external pressure.[297]

[294] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 184.
[295] China Power Project, How Deep Are China-Russia Military Ties?, *CSIS*, https://chinapower.csis.org/china-russia-military-cooperation-arms-sales-exercises/ (Accessed on 03.12.2022)
[296] Weinbaum, Cortney et al., "Assessing Systemic Strengths and Vulnerabilities of China's Defense Industrial Base", *RAND Corporation*, 2022.: 6-7.
[297] Azhar, Sana. The China-Taiwan Conflict & Global Microchips Supply, *The Paradigm Shift,* https://www.paradigmshift.com.pk/microchips/, August 26, 2022. (Accessed on 31.08.2022)

Russian disruptive play: Vast ambitions despite limited capabilities

Russia's approach to military innovation

Russia's approach to military innovation, based on strong overall state control, has not changed drastically since the end of the Cold War and the dissolution of the Soviet system. While the private sector is present in Russia, the largest producers and developers of military technology are all linked to the government, a legacy of the Soviet state-centric and planned system.[298] Overall, there are around 600 institutions and firms that research and develop military robotic systems across Russia.[299] It nevertheless relies on inputs from the private sectors, even if the policy orientation is always given by the state.[300] The Advanced Research Foundation (ARF), or FPI in Russian, is the central institution within the Russian Ministry of Defence that can be compared to DARPA. The ARF leads efforts to modernise the armed forces, particularly in the area of EDT. Other notable institutions include the Research and Testing Robotics Centre (RTRC) and the Commission for the Development of Robotic Systems for Military Purposes, which is headed directly by the Minister of Defence and is responsible for developing a unified approach across the various MoD departments.[301] Following a presidential decree in 2018, Russia founded the Technopolis ERA complex in Anapa, a sort of military Silicon Valley, to develop and test cutting-edge technologies. Emulating the *"(…) Chinese military-civilian fusion model, with science and technology parks being connected to the campuses of large military universities"*, ERA's creation illuminates the Russian government's effort to *"(…) develop an extensive – and still growing – defence R&D network of collaborating platforms, involving the armed forces and civilian state and private actors."*[302]

The Kremlin adapted its doctrines and structure more rapidly than expected.[303] According to RAND*, "Since 2008, the Russian military has undertaken an ambitious "New Look" reform to – among other things – replace or modernize 70 percent of its military equipment by 2020, increase the number of enlisted personnel, and overhaul the defence industrial base."*[304] The medium-term objective of this new strategy and doctrine was to integrate military robotics and automated systems to all levels of the Russian armed forces, by replacing 30% of the human soldiers with robots.[305] Another important document that was released in 2019, the *National Strategy for AI through 2030*, points out the importance of AI in future conflicts and preludes the establishment of a National Defence Management Centre that uses AI to collect, organise

[298] Naibadze, Anna. "Russian Perceptions of Military AI, Automation, and Autonomy". *Foreign Policy Research Institute (FPRI)*, January 2022.: 13.
[299] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022: Factsheet Russland.: 2.
[300] Bendett, Samuel et al., "Advanced military technologies in Russia. Capabilities and implications", *Chatham House*, 2021.: 9.
[301] Naibadze, Anna. "Russian Perceptions of Military AI, Automation, and Autonomy". *Foreign Policy Research Institute (FPRI)*, January 2022.: 16.
[302] Bendett, Samuel et al., "Advanced military technologies in Russia. Capabilities and implications", *Chatham House*, 2021.: 14.; 19.
[303] *Ibid.:* 47-50.
[304] Massicot, Dara. Anticipating a New Russian Military Doctrine in 2020: What it Might Contain and Why it Matters, *War on the Rocks*,: https://warontherocks.com/2019/09/anticipating-a-new-russian-military-doctrine-in-2020-what-it-might-contain-and-why-it-matters/, 9 September 2019. (Accessed on 27.09.2022)
[305] Jankowski, Dominik. "Russia and the Technological Race in an Era of Great Power Competition", *CSIS*, September 14, 2021.

and interpret information more effectively and enhance the armed forces' decision-making capabilities.[306]

An important doctrinal evolution was the development of the so-called New-Generation Warfare (NGW) in 2014 – also known as the "Gerasimov Doctrine" – named after the Army Chief of Staff General Gerasimov, which consists of minimising *"(…) the role of the large-scale military operations of the industrial war era and instead combines hard and soft power across military and nonmilitary domains. It capitalizes on indirect action, informational operations, paramilitaries, and special operations forces backed by sophisticated military capabilities, both conventional and nuclear."*[307] This doctrine augments the armed forces with innovative capabilities that flow from sensors to warfighters through reconnaissance-fire loops. It also relies on extensive nuclearisation at all levels of the force to deter conventionally and technologically superior adversaries.[308] Russia's "Gerasimov Doctrine" was tested during foreign interventions in Syria, Libya and Ukraine between 2011 and 2018. It has been highlighted in the Western media as a source of great strategic success for the Kremlin.[309] In 2019, the military establishment presented the paradigm of Active Defence (AD), which is based on the logic of pre-emptive neutralisation of an enemy trying to attack Russia.[310]

Although Russia appeared to have established a robust system for planning, developing, integrating and deploying military robotic systems, one of the most striking features of Russia's invasion of Ukraine in 2022 was their absence on the battlefields and, more generally, the technological limitations of Russia's armed forces.[311] It is difficult to say whether this is the result of Russian hybris or an inability to integrate these systems coherently into its military operations. What is clear, however, is that military robotics are much less central to the Russian way of war than official accounts make them out to be. Moreover, Russia appears to be deploying emerging technologies as combat-ready platforms even before these systems have completed the process of testing and adaptation.[312] So while the reforms and modernisation of the Russian armed forces were supposed to have been largely successful, the ongoing conflict in Ukraine shows that corruption, broken command structures and poor troop deployment are limiting Russia's military ambitions. In everything from logistics and military tactics to planning and targeting, the Russian armed forces have not performed as well as analysts expected.[313]

While Russia's military leaders have understood that they need to work more closely with the private sector to benefit from the spin-off of high-end technology to develop military robotics, their efforts are constrained by four main limitations. First, the preference for domestic supply chains exposes military innovation to unreliable and poor-quality components. Second, the authoritarian nature of Russian politics explicitly means declining standards of science and

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[306] *Ibid.:* 4
[307] Adamsky, Dmitry. "Russian Lessons from the Syrian Operation and the Culture of Military Innovation", *Marshall Center*, Report No. 047, 2020.
[308] Jankowski, Dominik. "Russia and the Technological Race in an Era of Great Power Competition"*, CSIS*, 14 September 2021.: 3.
[309] Ramani, Samuel. Russia's Strategy in Libya, *Royal United Services Institute (RUSI)*, https://rusi.org/explore-our-research/publications/commentary/russias-strategy-libya, 7 April 2020. (Accessed on 01.09.2022)
[310] Kofman, Michael et al., "Russia Military Strategy: Core Tenets and Operational Concepts", *Centre for Naval Analysis (CNA)*, 2021.: 10.
[311] Novak, Analisa. Russia's military "weaknesses are being revealed, says former commander of U.S. forces in Europe, *CBS News*, https://www.cbsnews.com/news/general-ben-hodges-russia-ukraine/, March 9, 2022. (Accessed 1 September 2022)
[312] Massicot, Dara. Anticipating a New Russian Military Doctrine in 2020: What it Might Contain and Why it Matters, *War on the Rocks*, https://warontherocks.com/2019/09/anticipating-a-new-russian-military-doctrine-in-2020-what-it-might-contain-and-why-it-matters/, 9 September 2019. (Accessed on 27.09.2022)
[313] Zabrodskyi, Mykhaylo et al. "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022", *Royal United Services Institute (RUSI)*, November 2022.: 43.

technology, even at Russia's flagship institutions such as Moscow State University. Third, Russia is suffering from a brain drain, with its best engineers and scientists leaving the country. Fourth, and most importantly, the impact of international sanctions on the Russian economy limits Russia's access to international technologies, thereby hampering its ability to innovate.[314] Indeed, the export controls put in place by the West as a whole – including major technological powers such as Japan, South Korea, Taiwan and Australia – have reduced Russia's capacity to produce industrial products, let alone advanced technologies.[315] Even before the war, Russia's defence industry was struggling, partly due to economic sanctions following the illegal annexation of Crimea in 2014.[316] Bottlenecks resulting from restricted access to key manufacturing components signal the limitations of the Russian defence industrial base and point to future weaknesses. Indeed, *"Russia's defence-industrial complex – especially military high-tech and AI research and development – may be affected by the international sanctions and cascading effects of Russia being cut off from semi-conductor and microprocessor imports."*[317]

Indeed, the export controls put in place by the West as a whole – including major technological powers such as Japan, South Korea, Taiwan and Australia – have reduced Russia's capacity to produce industrial products, let alone advanced technologies.

Given Russia's heavy reliance on technology transfer from foreign sources, there are currently no domestic solutions to replace the vacuum created by sanctions against Russia.[318] In addition, the fact that some 1,100 companies have left Russia since 24 February 2022 means that the Kremlin will not be able to acquire sensitive technologies, even through espionage or theft of intellectual property.[319] In semiconductors and microprocessors in particular, Russia has been severely sanctioned, including being blacklisted by Taiwan Semiconductor Manufacturing Company (TSMC), which controls 80% of the world market for certain types of advanced integrated circuits.[320] It is true that *"(…) Russia has made significant efforts to re-establish a network of suppliers in non-sanctioning countries from which to source semi-conductors due to their potential use in military applications."*[321] Through complicated transshipment routes and intensive use of third countries such as China, Turkey and post-Soviet states (Armenia, Belarus and Kazakhstan), Russia has been able to maintain minimal access to sensitive technologies, but at increasing cost. As a result, Moscow's ability to advance the roboticisation

314 Russia's economy can withstand a long war, but not a more intense one, *The Economist*, https://www.economist.com/briefing/2023/04/23/russias-economy-can-withstand-a-long-war-but-not-a-more-intense-one, 23 April 2023. (Accessed on 12.05.2023)
315 Kilcrease, Emily. Noteworthy: The New Russia Export Controls, *Center for New American Security (CNAS)*, https://www.cnas.org/press/press-note/noteworthy-the-new-russia-export-controls, 7 March 2022. (Accessed on 16.09.2022)
316 Johnson, Reuben. Russia's defense industry might not survive an invasion of Ukraine, *Breaking Defense*, https://breakingdefense.com/2022/01/russias-defense-industry-might-not-survive-an-invasion-of-ukraine/, 13 January 2022. (Accessed on 24.09.2022)
317 Bendett, Samuel. Russia's Artificial Intelligence Boom May Not Survive the War, *Defense One*, https://www.defenseone.com/ideas/2022/04/russias-artificial-intelligence-boom-may-not-survive-war/365743/, 15 April 2022. (Accessed on 14.09.2022)
318 Gorenburg, Dimitry et al., "A Technological Divorce: The impact of sanctions and the end of cooperation on Russia's technology and AI sector", *Center for Naval Analyses (CNA)*, 2022.: 3.
319 Economic Impact of Sanctions on Russia, *US Department of State*, https://www.state.gov/briefings-foreign-press-centers/economic-impact-of-sanctions-on-russia, 10 August 2022. (Accessed on 01.09.2022)
320 Whalen, Jeanne. Computer chip industry begins halting deliveries to Russia in response to U.S. sanctions, *The Washington Post*, https://www.washingtonpost.com/technology/2022/02/25/ukraine-russia-chips-sanctions-tsmc/, 25 February 2022. (Accessed on 02.09.2022)
321 Andrew, David et al. "Russia Shifting Import Amid U.S. and Allied Export Restrictions – China Feeding Russia's Technology Demands", *Silverado Policy Accelerator*, 2023.: 13.

of its armed forces is eroding, and it is likely that it will take decades for Russia to recover from the technological fallout of its invasion of Ukraine.[322] It is therefore possible that Russia will seek to copy the model of Iran, whose defence-industry has proven to be almost sanctions-proof by both acquiring oversea civilian technology and developing home-grown military robotics capabilities.[323]

Russia's doctrine developments in military robotics

Militarily, *"Russia is pursuing the development and fielding of aerial, ground and maritime autonomous and robotic systems as force multipliers (…)"* to strengthen the armed force's ability to perform.[324] For this reason, *"Russia's military leaders hope that soldiers can be replaced on the front line by semi-autonomous and remotely-operated military platforms."*[325] Russia is relatively ambitious about the doctrinal possibilities offered by autonomous and military robotic systems. It envisions at least eight roles for them: (1) offensive and first lines attackers aimed at breaking enemy lines, (2) support defensive operations, (3) artillery reconnaissance and support, (4) support for evacuation injured personnel, (5) engineering, ISR, minelaying, mine clearing, (6) biological and chemical reconnaissance, (7) logistics and transport of troops, munitions and equipment, and (8) patrolling and guarding.[326] Before 2022, Russia military staff claimed it had successfully integrated tactical UAVs at all level of the forces, from brigades down to platoons and groups.[327]

In 2016 the head of the ARF emphasised that the future conflicts were to be decided by military robotic systems. He stated: *"I see more and more robotization taking place.* [Future] *combat will be a war of operators and vehicles – the soldier will gradually turn into an operator and move away from the battlefield."*[328] A good illustration of this thinking is the reported development of FEDOR, a humanoid robot capable of carrying weapons and acting with a degree of autonomy.[329] In the concept of operations (CONOPS) of its armed forces, Russia envisages using its combat robots to locate and destroy an enemy, a technique that has been widely used in Syria. In Ukraine, Russia mostly use Orlan-10/30 and Forpost UAVs to provide *"(…) ISR and battle damage assessment capabilities to the Russian ground forces, including Rosgvardia and Wagner PMC."*[330] Military robotic systems will also be used in urban environments and will be an integral part of electronic warfare.[331] Given the negative demographic trends in Russia and the heavy loss of soldiers in the Ukraine conflict, military

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[322] Sheftalovich, Zaya and Cerulus, Laurens. The chips are down: Putin scrambles for high-tech parts as his arsenal goes up in smoke, *Politico,* https://www.politico.eu/article/the-chips-are-down-russia-hunts-western-parts-to-run-its-war-machines/, 5 September 2022. (Accessed on 24.11.2022)
[323] Edmonds, Jeffrey and Bendett, Samuel. "Russia's Use of Uncrewed Systems in Ukraine", *The Center for Naval Analyses (CNA)*, 2023.: 33.
[324] Bendett, Samuel et al., "Advanced military technologies in Russia: Capabilities and Implications", *Chatham House*, 2021.: 47.
[325] Nocetti, Julien. "The Outsider: Russia in the Race for AI", *Institut Francais des Relations Internationales (IFRI)*, 2020.: 26.
[326] Allik, Sten et al. "The Rise of Russia's Military Robots – Theory, Practices and Implications", *International Centre for Defence and Security*, February 2021.: 8-9.
[327] Edmonds, Jeffrey and Bendett, Samuel. "Russia's Use of Uncrewed Systems in Ukraine", *The Center for Naval Analyses (CNA)*, May 2023.: 4-5.
[328] Bendett, Samuel et al., *Improvisation and Adaptability in the Russian Military*, *Center for International and Strategic Studies (CSIS),* 2020.: 38.
[329] David Crane, Russian Robot Soldiers and Drone Swarms: Science Fact or Fiction?, *Defense Review*, https://defensereview.com/russin-robot-soldiers-and-drone-swarms-science-fact-or-fiction-meet-fedor-vikhr-whirlwind-and-smerch/, 19 April 2017. (Accessed 31.08.2022)
[330] Edmonds, Jeffrey and Bendett, Samuel. "Russia's Use of Uncrewed Systems in Ukraine", *The Center for Naval Analyses (CNA)*, May 2023.: 10.
[331] Allik, Sten et al. "The Rise of Russia's Military Robots – Theory, Practices and Implications", *International Centre for Defence and Security*, February 2021.: C-2.

planners and leaders believe that the pivot to military robotic systems could be an answer to protecting human capital.

Russia's capabilities in R&D of military robotic platforms [332]

Comparatively speaking, it is worth noting the limited financial support received by the ARF compared to DARPA and what China's state agencies invest in R&D of military robotics technologies. According to open-access data, Russia's ARF received for FY2021 an estimated USD 63 million, compared to USD 3.5 billion for DARPA and around USD 2.7 billion for China.[333] Given the limited financial support the ARF receives in Russia, it must prioritise certain areas over others in its current projects, and will not be able to compete with the US and China across the entire spectrum of AI and military robotics. However, it is difficult to know whether openly available data are accurate and reliable. Figures must therefore be treated as orders of magnitude.

Russia's development capabilities in military robotics depend on two important factors. The first is Russia's balance between the protection of its strategic interests and the doctrinal requirements of its force posture. The second is Russia's ability to develop and test its military robotic systems in various contemporary theatres of warfare and to assess their operational status. In any case, the official goal of robotising 30% of the country's military equipment by 2025, as stated in the 2008 modernisation strategy, cannot be considered a realistic target.[334] As detailed above, Russia's ability to develop, fund and deploy military robotics cannot support its growing geopolitical ambitions, creating an imbalance between means and ends. Moreover, Russia's war in Ukraine has largely exposed the shortcomings of the Russian armed forces, which some experts have dubbed the "Potemkin Army", highlighting that the Kremlin's purchase and development of military equipment such as aircraft, tanks and robots over the past decades would mask the fact that Russia is a second-tier military power, much less capable than was thought before February 2022.[335]

Compared to the US and China, Russia's defence innovation base lags behind, especially in the field of military robotics. Overall, Russia's ability to foster innovation is average. According to the Global Innovation Index, in 2022 Russia will rank 47th in the world, while the US will rank third and China will rank 11th.[336] Russia did not rank in the top 10, when it comes to scientific publications on AI and other EDTs.[337] Recent scholarship suggests that the Russian government's path to defence industrial base reform has been characterised by back-and-forth attempts to rebalance R&D efforts.[338] In addition, the Russian defence industry faces a major issue in scaling up production of UAVs and other unmanned systems, as its products struggle to capture niche markets.[339] The war in Ukraine will most likely decrease Russia's

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[332] A list of military robotic systems in service by the Russian armed forces can be found in the Appendix (Table 5).
[333] Naibaidze, Anna. "Russian Perspectives of Military AI, Automation, and Autonomy*", Foreign Policy Research Institute (FPRI)*, 2022.: 11.
[334] Sayler, Kelley. "Emerging Military Technologies: Background and Issues for Congress", *Congressional Research Service*, Report No. 46458, 2022.: 5.
[335] Shultz, Richard and Brimelow, Benjamin. Russia's Potemkin Army, *Modern War Institute,* https://mwi.usma.edu/russias-potemkin-army/, 23 May 2022. (Accessed on 02.12.2022)
[336] Dutta, Soumitra, et al. Global Innovation Index 2022., *World Intellectual Property Organization (WIPO),* 2022.
[337] Naibaidze, Anna. "Russian Perspectives of Military AI, Automation, and Autonomy", *Foreign Policy Research Institute (FPRI)*, 2022.: 21.
[338] Zysk, Katarzyna. "Defence Innovation and the 4th Industrial Revolution in Russia." *Journal of Strategic Studies* 44, No.4, June 7, 2021, 543–71.
[339] Edmonds, Jeffrey and Bendett, Samuel. "Russia's Use of Uncrewed Systems in Ukraine", *The Center for Naval Analyses (CNA)*, May 2023.: 19.

ability to innovate in the forthcoming years. Figure 12 describes the Russian military robotics market and its evolutions over the 2019-2025 period.

Platforms	2019	2020	2021	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	398	459	514	594	741	854	1004	17.1%
UGVs	90	105	125	153	200	243	301	23.4%
UMSs	-	6.2	14	23	39	57	82	67.4%
Total	**488**	**570.2**	**653**	**770**	**980**	**1154**	**1387**	**19.6%**

Figure 12 - Russia military robotic and autonomous systems market, USD million.[340]

UAVs have been integrated into almost all force structures, from the air force to the navy. While there has been a significant increase in the number of UAV systems deployed by the Russian armed forces over the past two decades, there are still certain limitations to the use of Russian UAVs. Recent research shows that Russia's UAV fleet is the second largest in the world, with around 2,100 aircraft, but most of these systems are of low quality.[341] Russian UAVs are primarily used for intelligence, surveillance, and reconnaissance missions and most of the systems that are used are small tactical UAVs such as the Sukhoi S-70 Okhotnik and the high-speed Grom UAV.[342] Russian UAVs are designed to be low-cost and expendable, able to sustain high attrition on the battlefield and remain a force multiplier.[343] Figure 12 highlights that the UAV domain is dominant within the field of military robotics in Russia. This market is expected to reach USD 1 billion by 2025, recording a yearly average increase of 17.16% between 2020 and 2025. As manifest from Russia's invasion of Ukraine, the investments into the R&D of UAVs over the past years have not come to pay off for Russia militarily.[344] Russia has mainly used Class I UAVs, and relatively few of systems of its own making.[345] A good example of Russian overconfidence in its capacities is the Orion UAV, which was supposed to be a game-changer in combat situations.[346] First deployed in 2020, the drone has not had a significant impact during the conflict, barely making an appearance on the battlefield.[347] There are other similar instances, where systems are fielded way too early in the development stage to make a difference on the battlefield. According to a report by the

[340] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 173.
[341] Alik, Sten et al., "The Rise of Russia's Military Robots", *International Centre for Defence and Security*, 2021.: 10.
[342] Bendett, Samuel and Edmonds, Jeffrey. "Russian Military Autonomy in a Ukraine Conflict", *Centre for Naval Analyses (CNA)*, 2022.: 4.
[343] Spencer, John and Bendett, Samuel. "Russian Military Technology and Urban Warfare", *Urban Warfare Project – Podcast*, 17 February 2023, https://open.spotify.com/episode/1iInY4EXh4z3kAoQ4iskpB?si=1brBvclhS-2tv4zqyGAXCQ&dd=1&nd=1. (Accessed on 17.04.2023)
[344] Bikram, Mittal. "Puzzling Out the Drone War over Ukraine", *IEEE Spectrum*, 2022.
[345] Bendett, Samuel. Russia Seems to Be Running Low on Drones, *Defense One*, https://www.defenseone.com/technology/2022/07/russia-seems-be-running-low-drones/374157/, 12 July 2022. (Accessed on 14.03.2023)
[346] Episkopos, Mark. Is the Orion UAV Russia's Answer to Ukraine's Turkish Drones?, *The National Interest,* https://nationalinterest.org/blog/buzz/orion-uav-russias-answer-ukraine%E2%80%99s-turkish-drones-198374, 22 December 2021. (Accessed on 28.09.2022)
[347] Cagaptay, Soner and Outzen, Rich. Turkey's Lethal Weapons, *Foreign Affairs*, https://www.foreignaffairs.com/articles/turkey/2022-04-27/turkeys-lethal-weapon., 27 April 2022. (Accessed on 26.09.2022)

American Foreign Policy Council (AFPC), a lack of expertise and high-tech components to build long-range attack drones is a reality in the Russian army, preventing it from conducting long-range reconnaissance missions like the US would.: *"Moreover, while Russia militarily has gained extensive experience operating a wide range of close and short-range UAVs and has commenced force-wide training and use of these unmanned systems, operating large and heavy drones would be a different story."*[348]

> *Significantly, because of Russia's severe structural limitations, the national defence innovation ecosystem cannot fulfil the Kremlin's demands and Russia's foreign policy appetite.*

UGVs have played a role in Russia's overall military planning in recent years, especially since the intervention in Syria. This prioritisation of UGVs goes hand in hand with Russia's traditional orientation as a land power and the importance of armoured vehicles within Russia's overall military culture.[349] The size of the Russian UGV market reflects this orientation, as it is the only area where Russia is in the same category as the US and China. It accounted for USD 90 million in 2019 and it is expected to more than triple by 2025, reaching USD 300.9 million. Syria provided an ideal environment to field and test UGVs in combat action and Russia has gained experience from these tests. The UGV Uran-9 was reportedly used in urban combat by Rusian troops and Wagner mercenaries.[350] The Russians are reportedly in the process of developing the combat UGV Vikhr based on the BMP-3 Infantry Fighting Vehicle (IFV).[351] Importantly, the increase in fielding and testing of UGV capabilities illuminates Russia's *"(…) desire to integrate UGVs more comprehensively into their [armed forces] capabilities."*[352]

Russia has not invested much in UMS. While there is a focus on the development of a fully autonomous submarine – the Poseidon, an unmanned nuclear-powered and nuclear-capable submarine – Russia lacks the indigenous technical expertise to advance developments in a short timeframe.[353] While Russia has launched many development projects, it is unlikely to achieve a breakthrough in this area in the foreseeable future. In addition, Moscow has deployed the Pioneer-M in 2020, a USV with ISR and mine countermeasure capabilities, but the system has suffered from bugs and other technical problems.[354] UUVs and USVs are not as high on the priority list of the Russian armed forces and political leadership compared to its R&D efforts for the development of UAVs and UGVs. It will be difficult for Moscow to compete with the greater capabilities of the US and China in this area. Therefore, in the field of UMS, Russia can be compared to regional military powers. The Russian UMSs market is likely to grow up to USD 81.8 million by 2025.[355] Figure 13 below shows the size of the Russian military robotics market in relation to the four other major European military powers, namely the UK,

[348] Bendett, Samuel. "The Rise of Russia's Hi-Tech Military", *American Foreign Policy Council (AFPC)*, 2019.: 4.
[349] Spencer, John and Bendett, Samuel. "Russian Military Technology and Urban Warfare", *Urban Warfare Project – Podcast*, 17 February 2023, https://open.spotify.com/episode/1iInY4EXh4z3kAoQ4iskpB?si=1brBvclhS-2tv4zqyGAXCQ&dd=1&nd=1. (Accessed on 17.04.2023)
[350] Uran-9 Combat Robot Deployment in Syria: Results, Issues And Prospects, *Veterans Today*, https://www.veteranstoday.com/2019/12/18/uran-9-combat-robot-deployment-in-syria-results-issues-and-prospects/, 18 December 2019. (Accessed on 01.09.2022)
[351] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 111.
[352] Alik, Sten et al., "The Rise of Russia's Military Robots", *International Centre for Defence and Security*, 2021.: 11-12.
[353] *Ibid.*
[354] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 171.
[355] *Ibid.*

Germany, France and Italy. Over the period 2019-2025, Russia's market will remain the largest by a significant margin. However, the markets of the aforementioned countries will grow faster than Russia's, diluting its lead in military robotics. Moreover, these projections were made before Russia's full-scale invasion of Ukraine in 2022, so it is highly likely that international sanctions will have a negative impact on the Russian military robotics market. Table 5 in the Appendix details the different types of military robotic systems currently in use or under development in Russia.

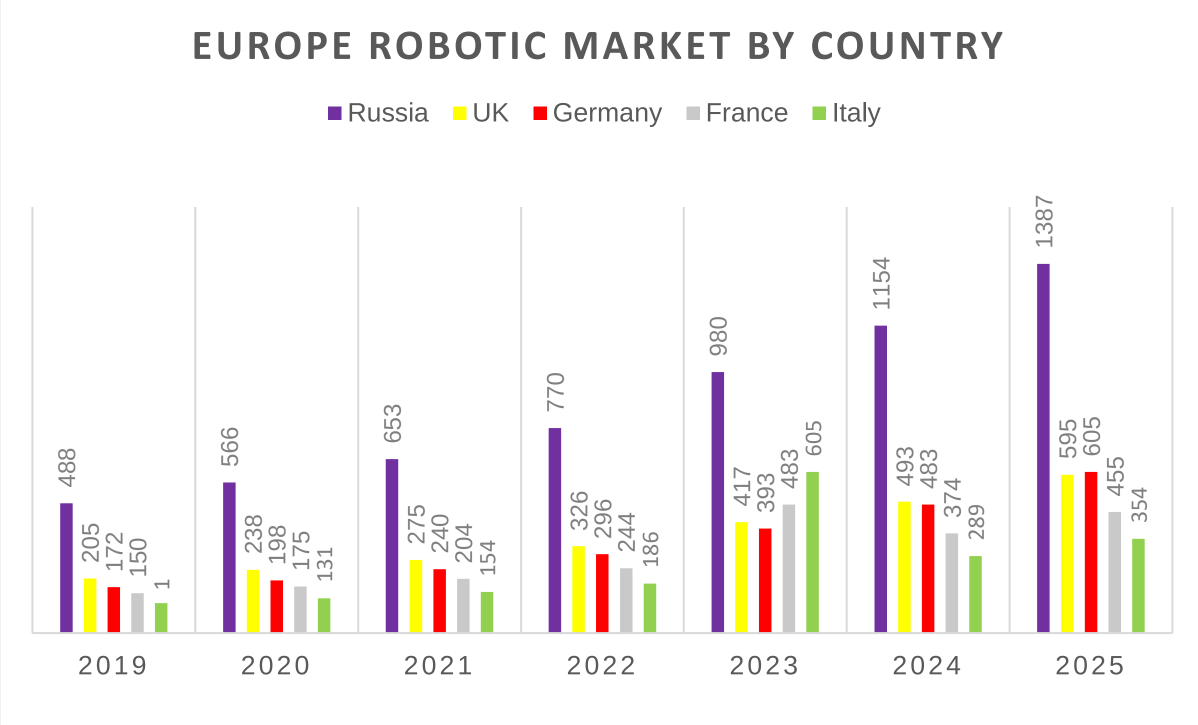

Figure 13 - Europe military robotic and autonomous systems market by country, (USD million).[356]

More recently, efforts have been made to create robot swarms that could be deployed by the Russian armed forces. Russia's interest in developing and catching up with the US and China in testing and deploying robotic swarms stems from its military culture, which sees the integration of asymmetric forms of warfare as fundamental to multiplying the strength of the Russian armed forces.[357] From the invasions of Peter the Great to the Great Patriotic War and the current conflict in Ukraine, Russia has historically relied on quantity over quality to prevail in conflicts. In this context, investing in swarms of drones makes sense both doctrinally and culturally. Over the past few years, there have been many robot swarm tests overseen by the Russian MoD.[358] One example is the *"(…) Molniya concept, which involves launching multiple jet-powered stealth drones from crewed and uncrewed platforms to conduct aerial and ground strikes and provide EW and reconnaissance capabilities."*[359]

[356] *Ibid.:* 159.
[357] Edmonds, Jeffrey et al., "Artificial Intelligence and Autonomy in Russia", *Center for Naval Analyses (CNA)*, 2021.: 111.
[358] Bendett, Samuel. Strengths in numbers: Russia and the future of drone swarms, *Modern War Institute*, https://mwi.usma.edu/strength-in-numbers-russia-and-the-future-of-drone-swarms/, 20 April 2021. (Accessed on 02.10.2022)
[359] Bendett, Samuel et al., "Advanced military technologies in Russia: Capabilities and Implications", *Chatham House*, 2021.: 52.

President Putin declared in 2018, "*Those who ride this technological wave will surge far ahead. Those who fail to do this will be submerged and drowned in this wave"*.[360] Russia was quick to recognise the need to integrate military robotics into its armed forces and has made significant progress in military robotics R&D. However, its efforts are constrained by a number of limitations, the first of which is the relative underfunding of the ARF. In particular, apart from the presence of UAVs, most other Russian robotic systems have significant limitations and are of relatively low quality. Russia is therefore a long way from fully autonomous weapons and lags behind the US and China. Significantly, Russia's national defence innovation ecosystem cannot meet the Kremlin's requirements and Russia's foreign policy ambitions due to severe structural limitations. It will not be able to compete with the US or China in the field of military robotics. Moreover, Moscow is likely to face significant financial and technological constraints in this area, primarily because of the foreign sanctions imposed on its economy by the West.

Conclusion: A military-tech competition not limited to the great powers

Comparatively speaking, the US, China and, to a lesser extent, Russia are leading the race in terms of R&D, testing and fielding of military robotics. While the US is leading the global race to field military robotic systems, China and Russia have political leaders and systems that are driving the integration and fusion of the civil and military domains. On the one hand, the state-led impulse to intensify efforts to robotise the armed forces gives them a specific structural advantage over the US. On the other hand, the sheer size of the US budget and the quality of its innovation architecture drive the US defence ecosystem to deliver significant breakthroughs. But China and Russia are also progressively adapting their military strategies: *"Today's militaries are still human-centric, and widespread use of military robots requires a significant re-evaluation of existing tactics and procedures to incorporate this new technology properly."*[361] Progress in the R&D of military robotic systems corresponds to the strategic and geopolitical interests of states. Russia is accelerating the transition to robotics in its armed forces in view of its declining demographics, while China's ambition to become the hegemonic power in the Indo-Pacific region is driving it to accelerate the development of UAV and UUV/USV capabilities. The US, for its part, seeks technological and military superiority in most domains to defend its interests and maintain its geopolitical primacy, leading it to invest heavily in advanced UAV, UGV and UMS capabilities. In this respect, the competition between these countries is an accelerating factor in the global R&D of military robotic systems, which some experts have described as a new arms race.[362]

An analyst stressed in 2019 that *"Presently, the international community is in the midst of an unprecedented change (…)"*, implying that a tectonic shift of power is currently ongoing and the shape of the future world order is today uncertain. In this regard, the pursuit of military robotic systems has and will continue to significantly change the way armed forces conduct combat operations and think about their military affairs.[363] Therefore, this growing competition in military robotics is not based solely on the strength of a state's defence innovation base or its financial resources, but is highly dependent on how armed forces find the best way to

[360] Showbridge, Michael. Putin's speech wasn't about weapons—it's worse than that, *Australian Strategic Policy Institute*, https://www.aspistrategist.org.au/putins-speech-wasnt-weapons-worse/, 14 March 2018. (Accessed on 03.10.2022)

[361] Bendett, Samuel. "Battle Robots Rivalry and the Future of War", *Valdai Papers*, 2019.: 6.

[362] Jones, Willie. Fueling a Robotic Arms Race Rocket propellant to make prosthetic arms better, stronger, faster, *IEEE Spectrum*, https://spectrum.ieee.org/fueling-a-robotic-arms-race#toggle-gdpr, 1 December 2007. (Accessed on 03.12.2022)

[363] Bendett, Samuel. "Battle Robots Rivalry and the Future of War", *Valdai Papers*, 2019.: 11.

integrate these systems into their planning and structure. In a sense, military robotics opens up new opportunities for states and non-state actors to play a decisive role in conflicts, allowing smaller powers to use asymmetric means to deter or even outmanoeuvre stronger adversaries. The development and pursuit of military robotic systems is therefore not only a competition between the great powers of the 21st century, but also involves second-tier or regional powers. Israel, Turkey and Australia have made headlines for their recent advances and investments in military robotic systems and are important examples of this dynamic.[364]

Israel

Along with the US, Israel is probably the most advanced country in the development and deployment of military robotic systems, particularly in the field of UAVs and UGVs.[365] Israel's efforts to advance its capabilities in this field are orchestrated by the Directorate of Defence Research and Development (DDRD), housed by the Ministry of Defence (MoD), which is *"(…) profoundly interested in 4IR technologies and is already engaged to varying degrees in the acquisition, development, and deployment of some of them."*[366] Israel is the leading country globally in allocating R&D spending to military purposes, with 4.94% of its GDP spent in defence in 2018.[367]

While Israel does not have a specific strategy defining the role of military robotic systems in its armed forces, its military-industrial complex is closely linked to the private sector, giving it a comparative advantage over other countries.[368] In the absence of strategic prioritisation, enormous institutional and structural forces are being mobilised to increase the roboticisation of the armed forces.[369] Leading private corporations particularly renowned for their R&D programs for UAVs are Elbit and Israel Aerospace Industries (IAI), which develop the Heron and Hermes type of UCAVs. According to an expert: strategically, *"the UAVs were enrolled as key pieces in enabling the IDF to control the battle rhythm and to choose the level of violence applied."*[370] UAVs in the Israeli Defence Forces (IDF) are used to enhance the operational capability and effectiveness of soldiers in combat, as well as to provide ISR. Recently, Elbit announced that it has been granted permission to develop technologies to enhance human-robot interfaces, which implies that the role of military robotic systems in the IDF is to enhance the operational capabilities of soldiers.[371] Israel is also a leader in UGVs, with at least three deployed systems: the Guardium and Jaguar, and has just announced the integration of a

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[364] European countries are discussed later in the study, in Chapter 3.
[365] Borg, Stefan. "Assembling Israeli drone warfare: Loitering surveillance and operational sustainability", *Security Dialogue*, Vol 52. No. 5, 2021.: 402.
[366] Evron, Yoram. "4IR technologies in the Israel Defence Forces: blurring traditional boundaries", *Journal of Strategic Studies*, Vol. 44 No. 4, 2021.: 577.
[367] Research and development expenditure (% of GDP) – Israel, 2021, *The World Bank*, https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=IL&most_recent_value_desc=true. (Accessed on 07.08.2022)
[368] Evron, Yoram. "4IR technologies in the Israel Defence Forces: blurring traditional boundaries", *Journal of Strategic Studies*, Vol. 44 No. 4, 2021.: 581 and 585.
[369] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022, Factsheet: Israel.: 4.
[370] Borg, Stefan. "Assembling Israeli drone warfare: Loitering surveillance and operational sustainability", *Security Dialogue*, Vol 52. No. 5, 2021.: 12.
[371] Elbit Systems, Israel Innovation Authority Approves the Establishment of a Consortium Led by Elbit Systems to Develop Human-Robot Interaction Technologies, *Elbit Systems*, https://elbitsystems.com/pr-new/israel-innovation-authority-approves-the-establishment-of-a-consortium-led-by-elbit-systems-to-develop-human-robot-interaction-technologies/, 16 December 2021. (Accessed on 09.09.2022)

multi-purpose semi-autonomous UGV light tank, the Robust.[372] Israel is using the Jaguar, a semi-autonomous system jointly developed by IDF and IAI, to patrol its border with Gaza. The system is seen as *"(…) a ground-breaking technological development—an independent robot that reduces the combat soldier's friction with the enemy and prevents risks to human life."*[373] Israel's military robotic systems can be consulted in Table 6.

Australia

In response to the perceived threat from China, Australia has announced that it will increase its defence budget in 2020 and plans to increase it by 40% by 2030.[374] The Russian attack on Ukraine was a wake-up call for Australia, which has since been reviewing the structure of its armed forces. As one senior Australian defence adviser put it: *"Australia no longer assumes a 10 year strategic warning time for defence planning, the Army must work quickly to address those challenges in implementing RAS* [Robotics & Autonomous Systems Strategy] *capability."*[375] Since 2018, Australia has recognised the importance of integrating robotics into its armed forces, particularly through the publication of two landmark Australian Defence Force (ADF) documents. It is only recently that Canberra has coherently integrated military robotics into its overall defence planning. In 2019, Canberra operated 10 types of UAVs, among which two were locally produced, the Aerosonde and the Avatar CX1 drones (see Table 6 in Appendix).

Australia enjoys certain advantages from its federal and liberal system, such as good complementarity between the needs of the armed forces and the defence industrial base.[376] The creation of dual-use technology incubators such as the Defence Innovation Hub (DIH) is a good example of Canberra's policy agility. Australia is also home to some of the leading companies in EDT and military robotics in particular, such as Ninox Robotics Ltd.[377] In addition, the institutional set-up that supports the defence innovation base enjoys domestic financial support, which has put Australia in a good position to develop military robotic systems.[378]

In 2020, Australia launched its Army's Robotic & Autonomous Systems Implementation & Coordination Office (RICO), to overhaul a common approach to the design, development, fielding and integration of military robotic systems.[379] Another interesting thread that could support Australia's advances in robotics is the implementation of the trilateral AUKUS partnership.[380] As well as the sharing of sensitive nuclear technology for submarines between

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[372] Saballa, Joe. Israel Introduces New Robotic Combat Vehicle, *The Defense Post*, https://www.thedefensepost.com/2022/06/14/israel-robotic-combat-vehicle/, 14 June 2022. (Accessed 02.09.2022)

[373] IDF, 'Jaguar': The IDF's Newest, Most Advanced Robot, The Future of Defending Israel 'Jaguar': The IDF's Newest, Most Advanced Robot, *IDF*, (www.idf.il), 4 April 2021. (Accessed 02.09.2022)

[374] Australian Government Department of Defence, Defence Strategic Update 2020, *Commonwealth of Australia*, 2020.: 7.

[375] Australian Army Research Centre, Robotics & Autonomy Systems Strategy v.2, *Robotic & Autonomous Systems Implementation & Coordination Office (RICO)*, August 2022.: 3.

[376] *Ibid.:* 21.

[377] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 178.

[378] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS) – Country Factsheet XY; *Center for Security Studies (CSS),* ETH Zürich (ed.), 2022, Factsheet: Australien: 3.

[379] Pierce, Melissa and Reynolds, Linda. "Morrison Government boosts investment in Army's autonomous vehicle fleet", *Australian Government Department of Defence*, 2020.

[380] AUKUS is a trilateral security pact ratified by the Australian, UK and US governments in September 2021. Its first aim is to allow for technology sharing, notably in the field of nuclear-propelled submarines. It is usually considered part of a larger US effort to strengthen strategic alignment with its allies in the Indo-Pacific region to cope with China's rise.

the UK, US and Australia, it is said to include other areas of security such as cyber, AI and quantum.[381] If military robotics is not explicitly identified as a collaboration domain as of now, it might well be in the foreseeable future: *"The true, long-term value of the AUKUS pact extends well beyond nuclear subs, and even beyond obtaining access to advanced US technologies: it's about collaborating on dual-use technology development."*[382]

Turkey

Turkey is another example of a state becoming a major global player in military robotics R&D. While Turkey was a minor player in defence exports in the early 2000s, largely due to its over-reliance on arms imports from the US, President Erdogan's ambitious plan to transform Turkey into an arms industry powerhouse is paying off. By promoting initiatives to increase domestic production and in-house expertise, Turkey has been able to reorient its national defence industry towards niche markets. A good illustration of this trend is the fact that *"The volume of R&D activities, the main driver of the defense industry's technological edge, has recently increased by 30 percent."*[383] In 2022, Turkey's private defence industry was worth USD 11 billion, and exports increased twentyfold between 2001 and 2021, with high-end products such as missiles, drones and frigates.[384] Turkey's assertive foreign policy under President Erdogan consumes large amounts of the defence industry's production. Indeed, *"Turkish military spending grew by 63 per cent in (…) 2012–21."*[385] Given Turkey's involvement in military conflicts, it has been able to test its systems in the field with remarkable results. As experts noted, Turkey's *"Bayraktar TB2 drones have helped push back Moscow's forces (…) in at least four different conflicts – Ukraine, Syria, Libya and in Azerbaijan's conflict with Armenia."*[386]

The performance of Turkish drones on several battlefields has allowed Ankara to distinguish itself in a niche market: high-end and relatively low-cost systems. Turkey's defence industrial base has been an early supplier of UAVs and has created places for its defence innovation base to produce military robotic systems. The best examples are Bayraktar Defence and Turkish Aerospace Industries (TAI), which produce the Bayraktar TB2 and TAI Aksangur respectively, both of which have won international acclaim for their battlefield efficiency and low maintenance costs.[387] These two unmanned platforms also illustrate an important development in the type of products offered by the Turkish defence industry: systems using intelligent technologies, capable of carrying heavier payloads and promoting more innovative

[381] Jowitt, Tom. AUKUS Security Alliance will include Cybersecurity, AI, Quantum, *Silicon UK*, https://www.silicon.co.uk/e-innovation/artificial-intelligence/aukus-security-alliance-will-include-cybersecurity-ai-quantum-416571, 16 September 2021. (Accessed on 02.09.2022)
[382] Bondy, Matthew. AUKUS Is Not Just about Subs: It's about Advanced Technology, *Centre for International Governance Innovation*, https://www.cigionline.org/articles/aukus-is-not-just-about-subs-its-about-advanced-technology/, 10 December 2021. (Accessed on 05.09.2022)
[383] Kasapoglu, Can. "Turkey". In: Mölling, Christian et al. "European Defense in A New Age (#EDINA) – Geostrategic Changes and European Responses Shaping the Defense Ecosystem", *Deutsche Gesellschaft für Auswärtige Politik (DGAP),* June 2023.: 63.
[384] Malsin, Jared and Kivilcim, Elvan. Drones, Unmanned Boats and Killer Robots Have Made Turkey an Arms-Industry Powerhouse, *The Wall Street Journal*, https://www.wsj.com/articles/drones-unmanned-boats-and-killer-robots-have-made-turkey-an-arms-industry-powerhouse-11658404887, 21 July 2022. (Accessed on 05.09.2022)
[385] Da Silva, Diego Lopes et al., Trends in World Military Expenditure, 2021, *Stockholm International Peace Research Institute (SIPRI)*, 2022.: 9.
[386] Malsin, Jared and Kivilcim, Elvan. Drones, Unmanned Boats and Killer Robots Have Made Turkey an Arms-Industry Powerhouse, *The Wall Street Journal*, https://www.wsj.com/articles/drones-unmanned-boats-and-killer-robots-have-made-turkey-an-arms-industry-powerhouse-11658404887, 21 July 2022. (Accessed on 05.09.2022)
[387] Witt, Stephen. The Turkish Drone that Changed the Nature of Warfare, *The New Yorker*, https://www.newyorker.com/magazine/2022/05/16/the-turkish-drone-that-changed-the-nature-of-warfare, 16 May 2022, (Accessed on 05.09.2022)

concepts of operation.[388] Turkey is in the process of acquiring a number of drone-carrying vessels, or "Lightning Carriers", modelled on LHD amphibious assault ships, which are normally designed to carry attack helicopters. The Turkish Navy is close to putting the TCG Anadolu to sea, and the Tuzla shipyard has already begun production of a sibling ship, the TCG Trakya.[389] Recently, Turkish conglomerate Otokar signed a cooperation agreement with Milrem, a leading European company on UGVs.[390] The Turkish MoD has reportedly launched a call for bids for the Medium-Class UGV Project destined to replace Turkey's ageing stock of M113 Armed Personnel Carriers (APCs).[391]

Turkey is therefore strengthening its role as an alternative source of military equipment, betting on its sustained efforts to achieve technological sovereignty in the midst of crescent tensions with the West. Despite sanctions on its economy, Ankara has indeed carved out a niche market for low-cost mid-range systems (especially UAVs), betting on the fact that it treats all potential client states on an equal footing, regardless of their values or domestic politics. In fact, *"Israel and Turkey have an edge over the middle eastern countries in the development of indigenous military robotic and autonomous systems."*[392] Table 6 in Appendix details the type of military robotic systems in use in the armed forces of Israel, Australia and Turkey.

[388] Kasapoglu, Can. Turkey's robotic warfare future in the skies, *Anadolu Agency*, https://www.aa.com.tr/en/analysis/analysis-turkey-s-robotic-warfare-future-in-the-skies-/1832430, 7 May 2020. (Accessed on 05.09.2022)
[389] Suorsa, Olli Pekka et Cannon, Brendon J. Les futurs porte-drones de la Turquie, *Le Rubicon*, https://lerubicon.org/publication/les-futurs-porte-drones-de-la-turquie/, 19 January 2023. (Accessed on 09.02.2023)
[390] Otokar & Milrem Robotics Teaming To Develop Unmanned and Robotic Systems, *Milrem Robotics*, https://milremrobotics.com/otokar-milrem-robotics-teaming-to-develop-unmanned-and-robotic-systems/, 30 September 2021. (Accessed on 06.09.2022)
[391] Ozberk, Tayun. Four robotic vehicles to compete for Turkish military contract, *DefenseNews*, Four robotic vehicles compete for Turkish military contract (defensenews.com), 6 July 2021. (Accessed on 05.09.2022)
[392] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 193.

Chapter 3: The European development of military robotic systems

This chapter examines how ten European countries and key institutions like the EU and NATO create, finance, and design defence innovation strategies within the European security ecosystem. The particular emphasis is on these entities' capacity to introduce, finance, and integrate robotics into their respective military forces. A trend is emerging among Europe's top military spenders to modify and interconnect their industry, educational system, and institutions to cooperate and advance in defence innovation.

This chapter assesses the capabilities of ten European countries. The chapter has an introduction and three sections. The introduction outlines how supranational institutions conceive and act on R&D for defence innovation and military robots. Section one presents the research methodology, while section two evaluates R&D funds and government financial incentives that support defence-related robotics innovation. The report analyses data and compares ten countries based on publicly available information. Section three provides specifics about each country in the comparison, starting with the UK – the biggest defence spender in Europe – and ending with Estonia – the smallest spender. Additionally, the report showcases the proficiency of each nation in defence innovation, their management of defence-related research and development, and their implementation of robotics in their military forces based on their military doctrine, tactics, and procurement policies. The study also analyses each country's investment in military robotic systems.

Methodology

This chapter looks into how defence innovation works in EU institutions, NATO and the ten European countries that matter the most. It studies how these countries organise innovation related to defence, the crucial organisations, how they work together, and how they use robotics in their military. It uses a case study method to highlight the similarities and differences in variables between chosen cases.[393] The case studies selected are ten countries identified based on the Stockholm International Peace Research Institute's (SIPRI) database on military expenditures. While in the top ten European countries in terms of military budget, Greece would rank among these countries with a military expenditure of USD 7.743 billion it was decided to include Estonia instead. Estonia is noteworthy due to its expertise in creating UGVs (Unmanned Ground Vehicles) through Milrem Robotics, a global leader in military robotics, which was founded in the country. Additionally, Estonia demonstrated effective technological and legal responses to Russian cyberattacks in 2007.[394] In terms of military budget, Estonia would rank 23rd in Europe, with a military budget of USD 704 million in 2021.[395]

The methodology of this study is mostly qualitative, based on literature and interviews, but it also includes quantitative elements. First, it uses the Technology Centre Mapping database which provides an indication of the academic and industrial ecosystem established in the

393 Priya, Arya. "Case Study Methodology of Qualitative Research: Key Attributes and Navigating the Conundrums in Its Application." *Sociological Bulletin* 70, No. 1, January 2021.: 94–110.: 96.
394 Delfrate, Valentina. "2007 Cyber Attacks in Estonia: A Case Study," *LUISS Guido Carli*, December 2021.: 5.
395 Hackett, James, ed. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS)*, 2022.: 100.

EU.[396] Second, the chapter compares European spending trends between EU Member States (MS) and their allocation of defence funds for research and development (R&D) and research and technology (R&T) programmes through the EDA's *Defence Data Portal*.[397] Also, the study uses the data from the BIS Report *Global Military Robotic and Autonomous (RAS) Systems Market, 2020-2025*, which offers wide-ranging data on the market size, types of systems, operations modes and applications of military robotics around the world.[398] In addition, the most recent brochure on the *EDA Defence Data, 2019-2020*, is reviewed for further elaboration on its findings.[399] This is complemented by the literature on robotic capabilities in Europe, through a wide array of books, journals, articles, and specialised websites as well as official documents, reports, briefs and academic papers.

In addition, the research team conducted ten interviews with experts and officials from relevant public institutions in the ten European case studies and Switzerland. The research team conducted in-person and virtual meetings from September 2022 until June 2023. For reasons of security and confidentiality, the research does not identify the interviewees unless they permit. The interviews help to enhance knowledge of the defence innovation ecosystems in Europe and the processes of developing and integrating military robots into armed forces across countries.

This methodology allows three different dimensions to be studied. First, it illustrates the actors/stakeholders in the national defence innovation ecosystem of each country. Second, it permits to detail the technology innovation space in defence-related R&D to identify the importance of the development of military robotics for each country's armed forces. Third, it explains how and why defence innovation has direct and indirect consequences for procurement processes, military doctrine, and strategy.

The European innovation ecosystem: between the EU and NATO

Significant alterations in the research and development and purchase of military equipment occurred over the last decade in Europe. To some degree, this event illustrates the advance of European unification. The past decades have indeed witnessed the EU embracing more and more initiatives in the field of defence and security: *"Examples of the EU's expanded ambitions in security and defense policy include the establishment of Permanent Structured Cooperation (PESCO) in 2017, the initiation of the European Defence Fund (EDF) in 2019, and the creation of the Directorate-General for Defence Industry and Space (DG DEFIS) in 2021, to name a few."*[400] In response to the current Russian-Ukrainian conflict, the EU Commission has recently announced that it would launch the Hub for EU Defence Innovation (HEDI).[401] Other initiatives such as the European Defence Industrial Development Programme

[396] Technology Centre Mapping, *European Commission*, https://ati.ec.europa.eu/technology-centre/mapping. (Accessed on 22.08.2022)
[397] Defence Data Portal, *European Defence Agency*, https://eda.europa.eu/publications-and-data/defence-data. (Accessed on 23.08.2022)
[398] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.
[399] EDA Defence Data 2019-2020, *European Defence Agency*, https://eda.europa.eu/publications-and-data/brochures/eda-defence-data-2019-2020. (Accessed on 05.05.2023)
[400] Csenartoni, Raluca. "The EU's Defense Ambitions: Understanding the Emergence of a European Defense Technological and Industrial Complex", *Carnegie Endowment for International Peace*, 2021.: 3.
[401] Factsheet: Hub for EU Defence Innovation (HEDI), *European Defence Agency*, https://eda.europa.eu/publications-and-data/factsheets/factsheet-hub-for-eu-defence-innovation-(hedi). (Accessed on 05.05.2023)

(EDIDP) and the Preparatory Active Defence Research (PADR) represent important parts of this growing EU legal and institutional framework to stimulate defence-related R&D in EDTs.

Given the current state of the European security architecture, the tensions between the US and Russia, and the significant decline in economic and diplomatic relations between Brussels and Moscow, along with the gradual loss of influence of multilateral organisations like the OSCE and the UN, the EU is taking on a more assertive strategic position. The EU's *Strategic Compass*, published in March 2022, emphasised the importance of promoting innovation in defence through greater collaboration and cooperation.[402] As one close observer argues, stakes are high: *"European states need to become more agile and efficient in addressing their defence requirements. If they do not, circumstances will dictate their choices."*[403]

EU institutions: integration of defence-related innovation funding

The most recent report from the European Defence Agency (EDA) on European defence expenditures states that *"2020 saw defence expenditure by the 26 EDA MS* [Member States] *rise for the sixth consecutive year. Taken together, EU MS allocated €198 billion to defence. Compared to 2019, defence expenditure increased by 5% despite the ongoing economic crisis caused by the COVID-19 pandemic"*.[404] This trend suggests a continual increase in military expenditure as a component of the total GDP of EU member nations. This trend has persisted since 2014, following the Russian illegal annexation of Crimea and the attack on the Donbas.[405] This trend escalated in response to the Russian invasion of Ukraine in 2022, which resulted in a significant increase in defence spending across the EU26 countries (total EU MS' defence spending are expected to reach almost EURO 300 billion by 2025).[406] Geopolitical events and their perceptions are driving European integration in defence and innovation without question. The European Defence Agency (EDA), an intergovernmental agency of the Council of the European Union, conducts R&D in 15 Capability Technology Areas (CapTechs), as well as aligning with member states' priorities. Presently, the EDA is undertaking 14 projects on robotics and RAS in the areas of air, land, and sea.[407]

Defence investments made by the members of the European Union states reached EUR 52 billion in 2021.[408] Among this figure, member states spent approximately EUR 8 billion on defence expenditure, mainly to maintain aging systems, and 36 billion on defence equipment procurement.[409] Furthermore, investments made by the EU27 in R&D have accounted for a figure comprised between EUR 7.565 and 10 billion in 2020, fluctuating on exactly which

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[402] A Strategic Compass for the European Union For a European Union that protects its citizens, values and interests and contributes to international peace and security, *Council of the European Union,* https://www.coe-civ.eu/kh/a-strategic-compass-for-security-and-defence-1, 21 March 2022. (Accessed on 07.09.2022)

[403] Grand, Camille. Strategy, capabilities, technology: A manifesto for new European defence*, European Council on Foreign Relations (ECFR)*, https://ecfr.eu/article/strategy-capabilities-technology-a-manifesto-for-new-european-defence/, 26 January 2023. (Accessed on 23.02.2023)

[404] EDA Defence Data 2019-2020, *European Defence Agency*, https://eda.europa.eu/publications-and-data/brochures/eda-defence-data-2019-2020. (Accessed on 05.05.2023).: 4.

[405] *Ibid.*

[406] Coordinated Annual Review on Defence Report 2022 (CARD), *European Defence Agency*, November 2022.: 2.

[407] Interview with EDA officials, 29 March 2023.

[408] For the previous and following chapter, USD is used as the reference currency. For obvious reasons, EU institutions release numbers in EUR. But as the exchange rate USD-EUR is extremely close to 1, one can consider for heuristic reasons that 1 USD = 1 EUR, even if that is not exactly accurate.

[409] Coordinated Annual Review on Defence Report 2022 (CARD), *European Defence Agency*, November 2022.: 2-3.

activities are taken into account (the UK was still part of the EU at this point).[410] As a result, collaborative defence R&D in Europe amounted to just EUR 140 million in 2020, a significant reduction from its peak of EUR 470 million in 2007. However, although a commitment was made by member states to reach the 35% threshold in PESCO, expenditures and investments in R&D are primarily made nationally. The same trend can be observed in joint equipment procurement between member states, which only accounted for 11% of total defence equipment procurement outlays in 2020.[411]

Despite EU efforts to stimulate defence-related innovation throughout Europe, member states continue to hold the majority of responsibility in this area. Indeed, the European Defence Equipment Market (EDEM), which serves as the regulatory branch of the European Commission for defence industry and contract awards, permits national preference in the contracting process, as stated in Article 346 of the Treaty on the Functioning of the European Union (TFEU).[412] This explains the fragmentation of the European defence sector, and the continued pre-eminence of national industries: *"(…) the European defense industrial base is not very European at all but instead made up of mainly nationally focused defense firms."*[413] Indeed, when compared to the US and China, the share of defence-related R&D is significantly lower in the EU27 countries. According to Josep Borell, High Representaitve for Foreign Affairs and Security Policy, *"Comparing the EU and its member states with other global actors, we lag (…) in (…) investing in defence innovation.* [Moreover,] *the gap is widening. (…) in 2020, EU member states spent only (…) 1.2% of the total European defence expenditure, with a tendency to further decrease in 2021-2023, whereas the related PESCO commitment sets the bar at 2% of the defence budgets. While most member states have increased their defence spending, they have not increased their investments in research and technology."*[414]

The European Defence Fund (EDF), launched by the EU Commission in 2018 as part of the European Defence Action Plan (EDAP), received EUR 2.651 billion for financing research projects at different stages of maturity over the 2021-2027 period.[415] In 2020, EDF's budget was raised to EUR 7.9 billion, marking a clear commitment by member states to increase joint R&D in new defence-related capabilities.[416] As noted by an Italian defence expert, the European commission is now the third most important investor in defence technologies across the EU, behind France and Germany.[417] EDF aims to enhance Europe's strategic autonomy in defence by combining research and development efforts, which will benefit member states with limited R&D resources. Additionally, EDF seeks to aid defence SMEs throughout Europe and encourage multinational collaboration across member states.[418] Hence, the EDF allocates

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[410] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 165.
[411] EDA Defence Data 2019-2020, *European Defence Agency*, https://eda.europa.eu/publications-and-data/brochures/eda-defence-data-2019-2020. (Accessed on 05.05.2023).: 10.
[412] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 168.
[413] Bergmann, Max and Svendsen, Otto. "Transforming European Defense – A New Focus on Integration", *Center for Strategic & International Studies (CSIS)*, June 2023.: 34.
[414] Borell, Josep. Defence innovation or defence irrelevance is the choice to make, *European Union External Action Service*, https://www.eeas.europa.eu/eeas/defence-innovation-or-defence-irrelevance-choice-make_en, 9 December 2021. (Accessed on 09.10.2022)
[415] Regulation (EU) 2021/697 of the European Parliament and of the Council of 29 April 2021 establishing the European Defence Fund and repealing Regulation (EU) 2018/1092, *Official Journal of the European Union*, 2021: Article 4 (Budget).: 162.
[416] *EUISS Yearbook of European Security : 2021,* European Union Institute for Security Studies (EUISS), LU: Publications Office, 2021.: 173.
[417] Tocci, Nathalie. "The Paradox of Europe's Defense Moment, Texas National Security Review, *University of Texas at Austin*, Vol. 6, Issue 1, Winter 2022/2023.: 101.
[418] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 168.

around one-third of its budget to research activities: *"Overall, if successfully implemented, the EDF and DG DEFIS are expected to significantly increase the commission's agenda-setting power in the field of security and defense R&D."*[419] Figure 14 below represents a simplified diagram of the relations between the main EU defence-related institutions.

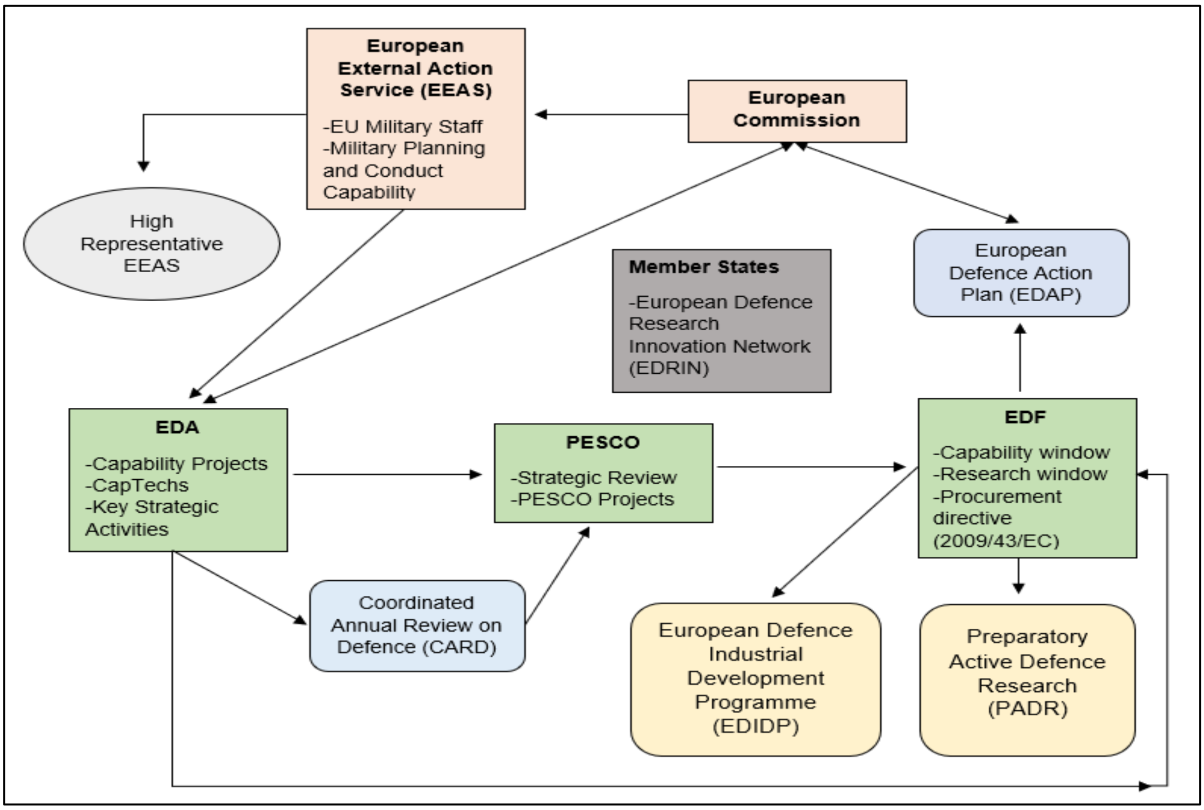

Figure 14 - Simplified diagram of the main EU defence institutions and their links.[420]

As the case studies from ten European countries show, some rely on EU-based projects to progress their defence innovation, despite national projects still being dominant. In the summer of 2020, the European Commission announced the reinforcement of two tools, EDIDP and PADR, under the EDF scheme to ease the integration of EU member states' industrial base and defence-related R&D. EDIDP aims at supporting the defence industry's innovation and competitiveness and received extra funding of EUR 205 million to support 16 projects on UGVs, AI and other EDTs.[421] PADR *"(…) is a concrete step aimed at assessing and demonstrating the added value of EU supported defence research and technology (R&T). The relevant results are expected to further deepen European defence cooperation addressing capability shortfalls and to strengthen European defence."*[422] The European Defence Research Innovation Network (EDRIN) is another tool of the EU to create synergies between MS' defence industrie, SMEs and start-ups with high potential.[423] EDRIN aims at developing new intergovernmental tools to identify critical technologies, such as the Observatory for Critical Technologies and the European Innovation Council.

[419] Csernatoni, Raluca. "The EU's Defense Ambitions: Understanding the Emergence of a European Defense Technological and Industrial Complex", *Carnegie Endowment for International Peace*, 2021.: 48.
[420] Figure made by the authors. *Sources:* Fiott, Daniel. EU Security and Defence – Metro Map, https://danielfiott.com/. (Accessed on 04.05.2023); Interviews.
[421] *EUISS Yearbook of European Security*, European Union Institute for Security Studies (EUISS), 2021.: 173.
[422] *Ibid.*
[423] EDRIN White Paper on the EU Action Plan on synergies, *European Defence Research Innovation Network (EDRIN)*, April 2019.: 1.

NATO Diana: EDTs as a transatlantic priority

The EU is not the main security organisation acting on the European continent, as this role is assumed by the North Atlantic Treaty Organization (NATO) since 1949. NATO is adapting to an ever more threatening strategic landscape and considers innovative military technologies as central to ensure deterrence and collective security.[424] The NATO Innovation Unit has developed two new instruments, namely the NATO Innovation Fund (INF) and NATO's Defence Innovation Accelerator for the North Atlantic (DIANA).[425] Other units such as the NATO Advisory Group on Emerging and Disruptive Technologies, the Allied Command Transformation (ACT) or the Science and Technology Organization (STO) are important tools of the organisation as well.[426] INF was announced in October 2021, receiving support from 17 states, with members intending to invest EUR 1 billion into allied innovation ecosystems over the next 15 years. Overall, the INF *"(…) aims to attract additional private investments due to the de-risking effect, both financial and technological, thanks to state co-funding and diligence and screening efforts."*[427] STO is committed to providing innovative solutions to NATO forces, ensuring that they maintain a technological advantage on the battlefield. As the largest supranational network for defence and security research worldwide, STO brings together scientists, engineers, analysts, industry professionals, and academics from many different countries. This cooperation is facilitated through Collaborative Programs of Work (CPoW), creating a dependable structure within NATO.[428]

> *There is a certain "division of labour" between NATO and the EU when it comes to stimulation of innovation in defence (…) EDF is more oriented towards financing the R&D of innovative capabilities, while DIANA is centred on harnessing EDTs by bringing together the private sector and the defence industry.*

DIANA is a tool to incubate and accelerate the development and adoption of dual-use technologies that can have military applications. This covers most EDTs and, of course, military robotics. It seeks at using a network of test centres and innovation incubators as well as selecting actors from the private domain. DIANA's primary purpose is to enable the pairing of dependable private investors with innovators. It also permits academic institutions to play a role in the defence innovation process. DIANA strives to utilise the innovation expertise of existing national bodies of NATO members by linking them through an inclusive transatlantic ecosystem. To achieve this, DIANA proposes five main priorities: (1) ensuring that innovations in ground defence align with NATO's security policies, (2) coordinating the identification of NATO's technological needs, (3) investing in a resilient innovation ecosystem across the NATO network, (4) prioritising frontline defence innovation, and (5) ensuring ongoing support for defence innovation within NATO.[429] DIANA's aim is to support all of the seven EDTs identified by NATO's Coherent Implementation Strategy: AI, big-data processing, quantum-enabled

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[424] Globesec, Adaptative Portfolio: Catalysing NATO's Performance Through Innovation, *NATO*, 5 March 2022.: 6
[425] NATO launches Innovation Fund, *NATO*, https://www.nato.int/cps/en/natohq/news_197494.htm?selectedLocale=en, 30 June 2022. (Accessed on 06.09.2022)
[426] Emerging and disruptive technologies, *NATO*, https://www.nato.int/cps/en/natohq/topics_184303.htm technologies, 17 October 2022. (Accessed on 18.10.2022)
[427] Hunter Christie, Edward. "Defence Cooperation in Artificial Intelligence: Bridging the Transatlantic Gap for a Stronger Europe." *European View* 21, No. 1, April 2022.: 19.
[428] NATO Science & Technology Organization - STO at a glance 2012-2022, *NATO*.: 2.
[429] Globesec, Adaptative Portfolio: Catalysing NATO's Performance Through Innovation, *NATO*, 5 March 2022.: 11.

technologies, autonomy, biotechnology, hypersonics and space.[430] The INF and DIANA exemplify NATO's ambition to ready itself for future war by reversing nearly three decades of budgetary reductions, inflexible bureaucratic structures, and national cultures that impede innovative collaboration among member states.[431] They also provide a framework for the convergence of Member States investing together in innovation and R&D in military capabilities *"(…) to foster technological cooperation among allies in NATO, promote interoperability and encourage the development and adoption of technological solutions."*[432]

Therefore, there is a certain "division of labour" between NATO and the EU when it comes to stimulation of innovation in defence, as DIANA and EDF do not have the same objectives. EDF is more oriented towards financing the R&D of innovative capabilities, while DIANA is centred on harnessing EDTs by bringing together the private sector and the defence industry.[433] Figure 15 identifies DIANA's footprint within the transatlantic space: its test centres, accelerators and regional offices.

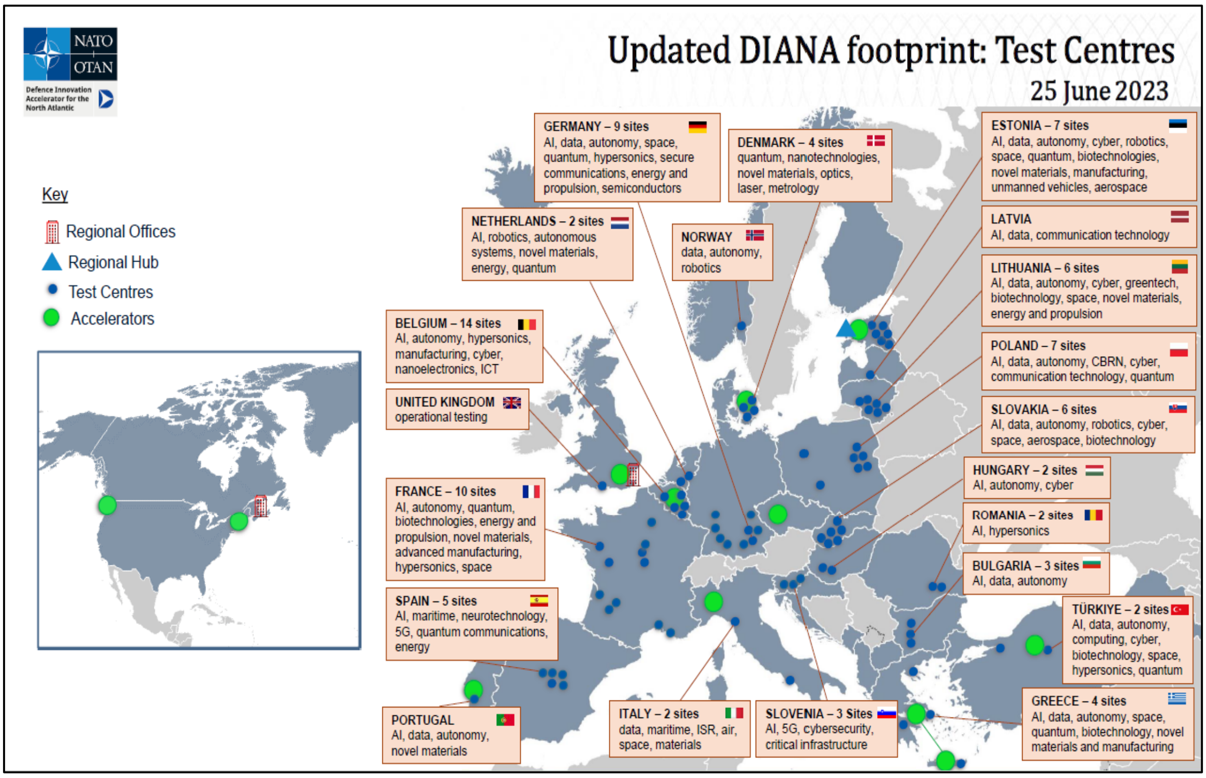

Figure 15 - The Defence Innovator Accelerator for the North Atlantic (DIANA), updated footprint 2023.[434]

[430] Turner, Joscelyn. DIANA – NATO's new Defence Innovation Accelerator, *ADS Group,* https://www.adsgroup.org.uk/blog/diana-natos-new-defence-innovation-accelerator/, 28 September 2021. (Accessed on 05.12.2022)
[431] Globesec, Reinvigorating NATO's Edge: Military Innovation the Strategic Concept, *NATO*, 16 May 2022.: 10.
[432] *Ibid.:* 6
[433] Bond, Ian and Scazzieri, Luigi. "The EU, NATO and European security in a time of war", *Centre for European Reform*, 5 August 2022.: 10.
[434] The Defence Innovator Accelerator for the North Atlantic (DIANA), *NATO*, https://diana.nato.int/ (Accessed on 28.06.2023)

Towards an integrated European-transatlantic defence innovation landscape?

Europe as a continent has a fragmented defence innovation landscape between the EU member states, the UK, Norway, Switzerland, the EU and NATO institutions. As one article puts it: *"*[Europe] *has* (…) *more than 25 different Pentagons, each with its own national procurement. This scattered landscape makes meaningful cooperation on procurement a huge political and bureaucratic undertaking."*[435] One might however consider the unique institutional integration of the European continent at large, which is matched by no other region in the world.[436] Logically, this European defence-related innovation ecosystem must be considered as several interrelated layers, varying in terms of administrative, financial, technological and political coordination, and oftentimes, lack thereof. Though the EU and NATO have improved their efforts to organise R&D and defence partnerships, member states still retain significant control over these initiatives. Important robotics projects fall under the coordination of several bodies within the EU, including the European Defence Agency (EDA), the EU Centre for Robotics and Artificial Intelligence Innovation and Excellence, as well as individual projects led by member states' MoD.[437]

Yet, *"European countries have not been starting their innovation approaches at the same time and do not share the same schedule and ambitions"*, which makes coordination between them highly complex.[438] Moreover, cooperation between EDA and NATO is limited in nature because of different agendas and priorities.[439] Another issue of concern is that European nations are increasing their defence spending, yet their joint cooperation on projects is decreasing. Consequently, it is likely that duplication of equipment and capabilities will persist, resulting in European armies being less effective than if they collaborated.[440] The conflict in Ukraine has strengthened this trend, as numerous European countries have been persuaded that collaborative procurement processes were overly time-consuming and that off-the-shelf purchases, primarily from non-European sources, would be more advantageous.[441] In fact, European states favour cooperation only when it coincides with their national defence industrial interests and planning.[442] Yet, the integration between EU and NATO instruments is strengthening, especially in the domains of defence capabilities and defence industry and research: *"Staff contacts on research and innovation developed to ensure mutual awareness on respective policy developments and initiatives related to emerging and disruptive technologies and defence innovation, notably the EU Defence Innovation Scheme (EUDIS), the Hub for EU Defence Innovation (HEDI) as well as NATO's Defence Innovation Accelerator*

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[435] Bergmann, Max and Besch, Sophia. Why European Defense Still Depends on America, *Foreign Affairs*, https://www.foreignaffairs.com/ukraine/why-european-defense-still-depends-america, 7 march 2023. (Accessed on 07.03.2023)
[436] The Future Institutional Evolution of the European Union, Briefing, *European Parliament Thematic Digest*, 19 November 2015.: 1.
[437] The EU Centre for Robotics and Artificial Intelligence Innovation and Excellence is part of the Directorate-General for Communications Networks, Content and Technology.
[438] Chiva, Emmanuel., "All the threats come together at the Defence Innovation Agency", *European Defence Matters*, Issue 22, 2021.: 18.
[439] Interview with EDA officials, 29 March 2023.
[440] Monaghan, Sean. "Solving Europe's Defense Dilemmas – Overcoming the Challenges to European Defense Cooperation", *CSIS*, *CSIS Briefs*, March 2023.: 1.
[441] Puglierin, Jana and Shapiro, Jeremy. "The Art of Vassalisation: How Russia's war on Ukraine has transformed transatlantic relations", *European Council on Foreign Relations (ECFR), Policy Brief*, April 2023.: 12.
[442] Coordinated Annual Review on Defence Report 2022 (CARD), *European Defence Agency*, November 2022.: 2-3.

for the North Atlantic (DIANA) and the NATO Innovation Fund, also with a view to identifying synergies."[443]

Military robotics heavily relies on spin-off and exchanges between state and private entities for dual-use technologies. As a result, integrating start-ups and SMEs into the culture of the defence industrial base (vertical market integration) poses a daunting task for military procurement planners.[444] Therefore, rather than considering a whole defence industrial base, robotics is co-dependent on multiple innovation ecosystems, composed largely of SMEs. They *"(…) represent a mix of networks with small and large firms, research centres and academic stakeholders"*, which provide the incentives for driving research and development on robotics and, more comprehensively, on defence innovation.[445] Indeed, the most important aspect of defence innovation remains the spin-off of research to battlefield operations.[446] Figure 16 provides an illustration of the cooperation between states, NATO, and EU institutions regarding the research and development, deployment, and fielding of military robotics by using the UAV market as an example of their overlap and integration.

UAV category	Characteristics	Competition
Medium Altitude Long Endurance (MALE)	Clusters of European companies competing for multinational projects	Limited competition
	Interdependency among nations	
	EDA as a key driver	
High Altitude Long Endurance (HALE)	Multinational projects because of the high costs of development	No competition
	NATO's tools as the principal driver	Almost monopoly by American platforms
Tactical UAV (Class II)	Medium interest in these platforms	Limited competition
	Limited thinking about their use	Potential for greater NATO-EU collaboration, especially in the maritime domain
	Diverse and uncoordinated market	
Small UAV (Class I)	Commercialisation in the civilian field	Strong competition
	Spill-over from the civilian sector	Emerging common European market
	Dynamic but unstructured market	American platforms as the most popular

Figure 16 - Key dynamics of the Europe unmanned aircraft vehicles (UAVs) Market.[447]

[443] "Eighth progress report on the implementation of the common set of proposals endorsed by EU and NATO Councils on 6 December 2016 and 5 December 2017", *the European Union and North Atlantic Treaty Organization*, 16 June 2023.: 8.
[444] Taylor, Trevo and Louth, John. "The challenge of change. Acquiring technologies for Defence in the UK", *RUSI Occasional Paper*, 2020.
[445] Merindol, Valérie and Versailles, David. "The (R)evolution of Defence Innovation Models", *Armaments Industry European Research Group (ARES)*, 2020.: 17.
[446] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies (IISS),* 2021.: 20.
[447] Figure made by the authors. *Sources*: Interviews; Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 155.

The importance of UAVs in both the North American and European military robotic markets makes for a significant case study, highlighting America's leading position in NATO defence markets.[448] Indeed, US-made Medium Altitude Long Endurance (MALE) and High Altitude Long Endurance (HALE) UAVs – both comprised in Class III, namely systems that weight more than 600 kilograms – are still largely dominant within the European market and *"(…) the continuing popularity of the U.S.-made small and tactical drones among European countries is linked not only to the fact that they are readily available, proven, and interoperable platforms, but also the experiences from past performances in the battlefield."*[449] Figure 16 illustrates that EDA is a vital contributor to R&D and production in the field of MALE, while NATO is the primary contributor for HALE.

While European countries have capabilities in developing and producing small UAVs, most HALEs and MALEs are still produced by US or by firms from a handful of western European countries, such as Airbus Defence and Space, BAE Systems or Thales.[450] The EU is anticipated to extend its involvement in the realm of Tactical UAVs (Class II, weighing between 150 and 600 kg) and Small UAVs (Class I, weighing up to 150 kg), in which numerous countries have either introduced or are currently producing their own systems (as shown in Table 7). NATO-EU collaboration is expected to play a crucial role in advancing the development of Tactical UAVs, with a particular focus on the maritime sector. An excellent illustration of this proposition is the OCEAN2020 initiative led by PADR, which involves 42 enterprises from 15 European and NATO participants. Table 7 in the Appendix presents a list of the UAVs operated by European nations.

[448] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 137.
[449] *Ibid.:* 155.
[450] *Ibid.*

Military robotics in European states: Enduring national preferences

Despite deepening European and transatlantic integration in defence-related innovation and R&D in recent decades, the primary pioneers of new military technologies remain the state actors involved in their development and deployment. Figure 17 provides data insight into how much each of the EU member states cumulatively and the ten European countries studied spend on military R&D. Data on these actors spendings on robotics R&D specifically is added, despite the fact that it is scarce. All countries are evaluated on their expenditure in 2020. The total sum of EU27 in defence R&D is EURO 7.564 billion, which is a significant number, even when compared to the US or China. France, and Germany spend the most on defence R&D. France spent EURO 1.3 billion in 2020 alone. The German Ministry of Defence allocated 3.19% of its annual military budget in R&D, which amounts EURO 1.55 billion.[451] In Germany, the *Hightech Strategy 2025*, integrated into the Ministry of Education and Research, is set to invest up to 3.5% of Germany's GDP into EDTs, of which robotics is a clearly stated sub-field.[452]

	Defence R&D spending	**Robotics spending**
EU27	7564 – 10000	828
UK (non-EU)	1250 (2020)	150
FRA	1300 (2020)	-
GER	1100 – 1550 (2020)	70-100
ITA	50 – 2000 (2020)	25-45
SPA	128.1 (2020)	-
NED	87.9 (2020)	-
NOR	85 – 121 (2018)	-
POL	53.2 (2017)	-
SWE	57 - 90.6	10-30
EST	3.1 (2019)	-
SWI	103 (2019)	10-25

Figure 17 - Spending on defence R&D and robotics in million EURO, in ten selected European countries.[453]

[451] Bundeshaushalt Digital. *Bundesministerium der Verteidigung*, https://www.bundeshaushalt.de/DE/Bundeshaushalt-digital/bundeshaushalt-digital.html. (Accessed on 28.09.2022)

[452] "Bericht der Bundesregierung zur Hightech-Strategie 2025 – Erfolgsmodell. Hightech-Strategie für ein starkes Innovationsland Deutschland", *Deutscher Bundestag, Unterrichtung durch die Bundesregierung*, 2021.

[453] Figure made by the authors. *Sources*: EDA Defence Data 2019-2020, *European Defence Agency*, https://eda.europa.eu/publications-and-data/brochures/eda-defence-data-2019-2020. (Accessed on 05.05.2023); For each country defence R&D spending: "Defence Innovation: New Models and Procurement Implications", *Armament Research European Group (ARES).;* Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.For each country robotics spending, numbers are indicative and based on hypothesis: World Robotics R&D Programs, *International Federation of Robotics Frankfurt (IFRF),* Informational Paper, 2021.; For Switzerland: Recherche et développement en Suisse 2019, *Office Fédéral de la Statistique (OFS)*, Département Fédéral de l'Intérieur (DFI), 2019.: 16; 71; Swiss Drone Industry Report 2021, *Drone Industry Association Switzerland (DIAS)*.: 16.

The UK and Norway are not EU27 members, but additional research provides their data collection. The UK spent EUR 1.25 billion on defence R&D in 2020-2021.[454] The UK has created an Industrial Strategy Challenge Fund as part of the UK Research and Innovation (UKIR). In April 2018, UKRI became a non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy.[455] Norway's defence R&D spending amounts to EUR 112.8 million. This sum represents the annual budget for 2020/2021 allocated to the Norwegian Defence Research Establishment.[456] The Horizon Europe Work Programme 2021-2022 indicates financial streams for robotics.[457] For Sweden, there are two programs through which the Swedish government has invested in robotics research: Robodalen (2003) and the Framework Grants for Research on Smart Systems (2016-2021).[458] As of 2020, Spain was believed to spend annually EURO 128.1 million in defence R&D, while the Netherlands (87.9), Poland (53.2), Estonia (3.1) and Switzerland (103) respectively spent less. For Italy, available data only provides a wide fork of plausible investment, namely between EURO 50 and 2000 million, which is not precise to allow a close examination.[459] Figure 18 illustrates the number of Advanced Technologies for Industry Technology Centres (ATITCs) in the European countries studied.

	Robotics/Human-Machine Interaction	Artificial Intelligence	UAVs	Robotics	Total
UK	-	-	-	10	10
GER	14	7	1	3	20
FRA	10	8	1	3	15
ITA	4	0	0	0	4
SPA	9	5	12	26	34
NED	5	0	0	0	5
POL	1	0	1	1	3
NOR	-	-	-	-	-
SWE	0	0	0	0	0
EST	1	1	0	0	2
SWI	2	3	2	9	16

Figure 18 - Number of Advanced Technologies for Industry Technology Centres (ATITCs), in ten selected European countries. [460]

[454] United Kingdom Ministry of Defence, *MOD Departmental resources*, https://www.gov.uk/government/statistics/defence-departmental-resources-2021/mod-departmental-resources-2021. (Accessed on 27.08.2022)
[455] Robots for a safer world challenge, *UKIR*, https://www.ukri.org/what-we-offer/our-main-funds/industrial-strategy-challenge-fund/future-of-mobility/robots-for-a-safer-world-challenge/. (Accessed on 20.09.2022)
[456] Proposisjon til Stortinget (forslag til stortingsvedtak), Prop. 1 S (2020 –2021), *Norwegian Government*, 2020.: 158.
[457] Horizon Europe Work Programme 2021-2022, Digital, Industry and Space, *European Commission*, 2022.: 97.
[458] World Robotics R&D Programs, *International Federation of Robotics*, 2021.: 65-69.
[459] Technology Centre Mapping, *European Commission*, https://ati.ec.europa.eu/technology-centre/mapping. (Accessed on 30.09.2022); Swiss Robotics Ecosystem, *Swiss National Centre of Competence in Research (NCCR)*, https://nccr-robotics.ch/knowledge-and-tech-transfer/swiss-robotics/ (Accessed on 07.03.2023)
[460] Figure made by the authors. *Sources*: Technology Centre Mapping, *European Commission*, https://ati.ec.europa.eu/technology-centre/mapping. (Accessed on 30.09.2022); Swiss Robotics Ecosystem, *Swiss National Centre of Competence in Research (NCCR)*, https://nccr-robotics.ch/knowledge-and-tech-transfer/swiss-robotics/ (Accessed on 07.03.2023)

> *Four main factors accelerate defence innovation: (1) Threat and vulnerability perceptions; (2) Convergence in political, military, and societal support for defence innovation; (3) Innovation organisation and governance; and (4) Investment in defence-related innovation.*

The ATITCs serve as representatives of the innovation ecosystem within both civilian and defence sectors. In the context of our study, these ATITCs are defined as public or private organisations that engage in applied research and innovation activities focused on dual-use technologies, which possess potential military applications. It is important to note that the existence of these ATITCs does not guarantee automatic translation of innovation into the defence realm. However, the research projects and technologies developed by these centers are predominantly of a dual-use nature. Consequently, it is reasonable to acknowledge the active participation of these institutions in the advancement of military robotics within the countries under examination. Specifically, our study focuses on ATITCs involved in research pertaining to four key areas related to military robotics: (1) robotics and human-machine interaction, (2) artificial intelligence, (3) unmanned aerial vehicles (UAVs), and (4) robotics in general. It is worth mentioning that due to the inclusion of two non-European Union member states, namely the United Kingdom and Norway, in our analysis, information regarding their respective ATITCs is not available. However, through desk research, we were able to identify ATITCs in the UK that specifically concentrate on robotics. Unfortunately, there is insufficient data accessible for Norway. Conversely, additional research identified a total of 16 ATITCs in Switzerland.

According to recent analysis conducted by the IISS, four main factors influence defence innovation: (1) threat and vulnerability perceptions, (2) convergence in political, military, and societal support for defence innovation, (3) innovation organisation and governance, and (4) investment in defence-related innovation.[461] These factors are interrelated and must be considered simultaneously. This chapter provides an in-depth analysis of the applicability of the four innovation drivers to the ten most significant European countries. It sheds light on their strategic positioning, institutional framework, innovation conceptualisation, defense-related industrial foundation, and military doctrine. The study further demonstrates that the ten selected cases are currently undergoing diverse trajectories in the integration of robotics into their armed forces, owing to their unique internal capabilities, the presence or absence of a defense industrial base, and strategic preferences.

Some states are pushing faster for integration than others. Notably, *"(…) the transformation speed depends on national cultures."*[462], strategic objectives and financial resources. The study illustrates the driving role of the civil industry in accelerating military robotics R&D. The empirical analysis of the four drivers of defence innovation indicates that *"(…) the phenomenon of defence innovation implies deliberate technological, organisational and doctrinal change away from the status quo, aimed at responding to a new strategic environment and achieving strategic advantage and competitiveness, including but not only to warfighting."*[463]

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[461] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies*, 2021.: 3.
[462] Merindol, Valérie and Versailles, David. "The (R)evolution of Defence Innovation Models", *Armaments Industry European Research Group (ARES)*, 2020.: 6.
[463] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies*, 2021.: 7.

United Kingdom (UK)

The United Kingdom has established an intricate ecosystem that facilitates the organisation and advancement of innovation endeavours involving the armed forces, industry, and academia. Consequently, the UK reaps the advantages of a defence innovation architecture characterised by a triangular framework, relying on *"(…) 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."*[464] The main perception of threats and vulnerabilities, the first factor driving defence-related innovation, can be summed up as the UK witnessing authoritarian regimes' assertiveness among competitors – Russia and China – but also within allies, such as Turkey.[465] Brexit, accompanied by a subsequent reconciliation with the Anglo-Saxon nations exemplified by the AUKUS pact, as well as the United Kingdom's assertive pursuit of its geoeconomic interests in the Indo-Pacific regions, serve as additional driving forces behind the alterations observed in London's foreign policy. These developments collectively emphasise the underlying justification for the concept of "Global Britain".[466] Interestingly, some of these elements were made clear as early as 2015, with the publication of the *National Security Strategy* and *Strategic Defence.* The acceleration of the destabilisation of the international caused by Russia's attack on Ukraine and China's aggressiveness was further highlighted in a document entitled *Integrated Review Refresh 2023,* published by the Sunak government.[467]

Recent publications of the UK government from 2021 indicate that defence innovation permeates the strategy of the MoD.[468] Indeed, *"(…) the UK has developed a dense ecosystem of R&D&I agencies, including the Dstl* [Defence Science and Technology Laboratory], *the UK's Strategic Command's JHUB, the Ministry of Defence's new AI Centre and the new civil-military Technology Accelerator, which cover both front and back-end innovation comprehensively, in similar ways to the US system."*[469] Institutionally, the United Kingdom has implemented a number of foundational elements to facilitate the advancement of defence innovation. The JHub serves as a central hub for expediting the transition of civilian innovations from the private sector to defence entities. Its primary objective is to identify and meet the requirements of the UK armed forces, thus it evaluates, appraises, and transfers dual-use technologies to the military. The Defence and Security Accelerator (DASA) and the Frontline Command Innovative Centre (FCIC) assume a more nuanced role by fostering collaborations with non-traditional defence actors, fostering the development of technologies and projects at low Technology Readiness Levels (TRLs).[470] Those are also the main interfaces used by the UK government to foster innovation in the military domain and push for a comprehensive integration of new capabilities into the armed forces. It seeks to provide new market entries with sufficient buy-in incentives as research has concluded that at least ten ATITCs in the UK do research in the field of robotics.

[464] "Advantage through Innovation: The Defence Innovation Initiative", *Ministry of Defence*, 2016.: 4.
[465] Seely, Robert, and Rogers, James. "Global Britain: A Twenty-First Century Vision". Global Britain Programme, *The Henry Jackson Society*, 2019.: 17.
[466] Barry, Ben et al., "The UK Indo-Pacific Tilt: Defence and Military Implications", *International Institute for Strategic Studies (IISS)*, London, June 2022.: 17.
[467] "Integrated Review Refresh 2023: Responding to a More Contested and Volatile World"*, His Majesty Government,* 2023.: 6.
[468] "Defence and Security Industrial Strategy: A strategic approach to the UK's defence and security industrial sectors", *Her Majesty Government*, 2021.
[469] Soare, Simona and Pothier, Fabrice. "Leading Edge: Key Drivers of Defence Innovation and the Future of Operational Advantage", *The International Institute for Strategic Studies (IISS)*, 2021.: 21.
[470] Interview at the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.

Another central actor is the MoD's Future Capability Group (FCG) created to accelerate defence-related projects, smoothen R&D processes and provide the British armed forces with effective, reliable and innovative equipment.[471] By creating these initiatives, the UK government addressed a key problem of the British innovation ecosystem: the overall private expenditures in the public sector increased by an average of 2.7% since 1991, while the spending by private actors in the defence sector decreased by 1.8% over the same period.[472] To resolve this problem of investment, the MoD created another tool, the Co-Investment Defence Innovation Framework (CODIFI), aimed at sustaining high level of private investments.[473] As shown in Figure 17, the UK government spent EURO 1.25 billion in 2020 on military R&D.

In the context of the United Kingdom, all four of the factors driving innovation are prominently influencing and facilitating the progress of defense innovation. Firstly, the escalation of strategic threats has necessitated the need for innovative solutions. Secondly, the government has taken proactive measures to reinforce its governance framework for fostering innovation. Thirdly, there is a growing consensus within society and the political sphere regarding the significance of geopolitical matters. Lastly, the convergence of the nation's capabilities in developing cutting-edge technologies specifically tailored for military purposes has further fueled the drive for innovation.

The UK government concentrates its efforts in five directions to stimulate the defence R&D ecosystem.[474] First, it seeks to create a pull factor for capturing investors and to encourage the industry to support efforts to accelerate defence innovation. The FCG plays a pivotal role in this endeavour by serving as a nexus that connects the defence industry, SMEs, academic institutions, and government agencies, thereby reducing R&D cycles and enhancing efficiency in delivery.[475] Second, the UK collaborates with various partners in advancing defence innovation (especially the US, NATO members, Japan, Australia and others).[476] Third, the military integration of commercial/civil innovation has altered previous industrial strategies by setting up the Innovation and Research Insights Unit (IRIU) and the UK Research and Innovation sub-department within the Department for Business, Energy and Industrial Strategy. The Dual Use Technology Exploitation (DUTE) is another initiative led by the MoD to boost UK economic growth by enabling companies to draw upon dual-use technologies.[477] Fourth, the MoD has accelerated the pace of R&D, which results in shorter military innovation production cycles. Fifth, the MoD has sought to augment its financial incentives for defence innovation, which had previously been relatively scarce. DASA (equivalent of USD 49 million received in 2020-2021) and the Defence Innovation Fund (equivalent of USD 900 million allocated for 2015-2025) receive less money on an annual basis than efforts on defence innovation in France or Germany, but both institutions' funding are growing.[478] In 2019, the UK

[471] *Ibid.*
[472] Industry for Defence and a Prosperous Britain: Refreshing Defence Industrial Policy, *UK Ministry of Defence*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/669958/DefenceIndustrialPolicy_Web.pdf, 2017. (Accessed on 09.09.2022)
[473] *Ibid*.
[474] Taylor, Revor. "Defence Innovation: New Models and Procurement Implications. The British Case", *Armament Industry European Research Group* (ARES), 2021: 9-13.
[475] Interview at the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.
[476] Industry for Defence and a Prosperous Britain: Refreshing Defence Industrial Policy, *Ministry of Defence UK*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/669958/DefenceIndustrialPolicy_Web.pdf, 2017. (Accessed on 09.09.2022)
[477] *Ibid.:* 33.
[478] Annual Review 2020/2021, *Defence and Security Accelerator (DASA)*, https://express.adobe.com/page/myVPZ8baX7UwF/. (Accessed on 17.09.2022)

As the most advanced country in developing military robotics in Europe (Russia excluded), the UK has embraced an energetic and wide ambition to field all types of unmanned systems in a near future.

MoD granted funds worth USD 83.8 out of 203.3 of the Transformation Fund to hasten the development of military robotics.[479]

The United Kingdom, excluding Russia, stands as the foremost nation in Europe in terms of advancements in military robotics. With great engagement and a broad vision, the UK has wholeheartedly embraced the objective of deploying a comprehensive range of unmanned systems in the foreseeable future. In 2020 the Chief of the Defence Staff said, during an interview with The Guardian that *"Robot soldiers could make up* [a] *quarter of British army by 2030s"*.[480] Doctrinally, the UK's robotisation effort foretells: (a) Robotic and autonomous systems enabled teams, (b) integrated teams, and (c) supervised teams.[481] To this extent, the establishment of the Expeditionary Robotics Centre of Expertise (ERCoE) was an important mark, allowing the military to test its equipment *"(…) in simulated military scenarios."*[482] ERCoE is a textbook example of what FCG can do: it gathers people from different backgrounds, initiates cooperation, stimulate innovation and allow reiteration of contacts.[483] The UK has published several documents on military doctrine, one specifically on UAVs and the other on human-machine interaction.[484] Furthermore, the UK's 2019 *Equipment Plan* states that current Army Command programmes *include "utilising the Defence Transformation Fund to deliver innovative capabilities in accelerated timelines including: Unmanned Air Systems, robotic platoon vehicles, development and trailing of autonomous systems to revolutionise logistic support and to deliver information manoeuvre."*[485] Figure 19 below highlights the types of robotic systems developed by the UK and the market size for each type. In general, the doctrine of the British army is founded upon an expeditionary tradition, which posits that a force possessing superior technology would emerge victorious through the implementation of rapid offensive maneuvers that would neutralise a numerically superior adversary. However, it has been contended that contemporary UGVs exhibit commendable performance in defensive missions, such as patrolling and maintaining control over terrain. The United Kingdom is currently endeavouring to develop UGVs that could function as "loyal wingman Infantry Fighting Vehicles (IFVs)" and exert a substantial influence on offensive operations conducted on the battlefield.[486]

The UK is investing in all types of military robotic systems: UAVs, UGVs and UMSs. Overall, the military robotics market is expected to grow by a yearly average of 17.36% between 2020 and 2025. The UK UAV market is larger, London being a pioneer of this domain alongside its

[479] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 162.
[480] Sabbagh, Dan. "Robot soldiers could make up a quarter of British army by 2030s", *The Guardian*, https://www.theguardian.com/uk-news/2020/nov/08/third-world-war-a-risk-in-wake-of-covid-pandemic-says-uk-defence-chief, 8 November 2020. (Accessed on 15.09.2022)
[481] Ebbut, Giles. British Army eyes new RAS strategy, *Janes*, https://www.janes.com/defence-news/news-detail/british-army-eyes-new-ras-strategy, 29 March 2021. (Accessed on 18.09.2022)
[482] Industry for Defence and a Prosperous Britain: Refreshing Defence Industrial Policy, *UK Ministry of Defence*, 2017.: 32.
[483] Interview the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.
[484] Joint Doctrine Publication 0-30.2. Unmanned Aircraft Systems, *UK Ministry of Defence*, 2017.; Joint Concept Note 1/18. Human-Machine Teaming, *UK Ministry of Defence*, 2018.
[485] Defence Equipment Plan 2019, *UK Ministry of Defence*, Updated 2020.: 34.
[486] Interview the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.

American ally since having conducted joint tests on HALEs as early as 1988.[487] It is therefore not a surprise that the market is larger for this type of capability. The UK UAV market is expected to reach USD 478 million in 2025, up from 189 in 2019. An illustration of this is the development of the Next Generation Rotorcraft Capability (NGRC) with other NATO partners, which is supposed to replace London's fleet of ageing UH-60 helicopters.[488] The UK has also produced indigenous types of UAVs, the Watchkeeper, the Malloy and the Protector among others (refer to Table 7 in Appendix for details).[489] In late 2022, the UK announced alongside Italy and Japan the signing of an "international coalition agreement" to build a sixth-generation multirole and collaborative aircraft, the Global Combat Air Programme (GCAP).[490]

Platforms	2019	2020	2021	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	189	215	243	281	351	406	478	17.4%
UGVs	16	20	25	32	45	57	74	30.5%
UMSs	-	3.6	7	13	21	31	44	65.4%
Total	**205**	**238.6**	**275**	**326**	**417**	**494**	**596**	**20.1%**

Figure 19 – UK military robotic and autonomous systems market, USD million.[491]

As shown in Figure 19, the UGVs market is expected to reach USD 74 million in USD in 2025. The British Army expects a lot of next-generation UGVs and intends to disperse them within all its force structures. The British armed forces and ERCoE are currently testing four types of UGVs (Milrem Robotics' THeMIS and Type-X, Rheinmetall's Wiesel and Elbit's Robust) and will conduct runs with weapons on them in 2023.[492] The maritime domain presents a promising area for investment and development of military robotics in the United Kingdom. London's rich history of sea power and its proficiency in deploying some of the world's largest and most efficient vessels make it a natural leader in this field. This assertion is supported by the development of an indigenous type of XLUUV by the DASA for the purpose of conducting intelligence and antisubmarine warfare missions. As Admiral Radakin stated, *"These XLUUVs are at the forefront of underwater systems technology; UK technological developments such as this will be key to the Royal Navy maintaining its battle-winning edge in the underwater*

[487] Jones, R. I. "The Design Challenge of High Altitude Long Endurance (Hale) Unmanned Aircraft." *The Aeronautical Journal,* No. 1024, June 1999.: 277.
[488] Machi, Vivienne. NATO helicopter program could be next battleground between US, European defense industries, *Defense News*, https://www.defensenews.com/smr/nato-priorities/2021/06/14/nato-helicopter-program-could-be-next-battleground-between-us-european-defense-industries/, 14 January 2021. (Accessed on 08.09.2022)
[489] Gettinger, Dan. "The Drone Databook", *The Center for the Study for the Study of the Drone at Bard College*, 2019.: 149.
[490] Martin, Tim. UK, Japan and Italy launch Global Combat Air Programme to deliver next generation fighter, *Breaking Defense*, https://breakingdefense.com/2022/12/uk-japan-and-italy-launch-global-combat-air-programme-to-deliver-next-generation-fighter/, 9 December 2022. (Accessed on 08.05.2023)
[491] Figure made by the authors. *Source*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 165.
[492] Interview the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.

environment."[493] Former Defence Minister Wallace announced in December 2022 that Project Cetus had entered its final stage, and that this XLUUV will be the largest unmanned maritime system operated by a European navy.[494] The UMSs market – growing from USD 3.6 million in 2020 to an expected USD 44 million in 2025 – represents the highest increase among all types of robotic military systems for the UK. Considering London's significant financial capabilities, its extensive involvement in crucial military and strategic alliances, alongside its progressive and efficient defence innovation ecosystem, it is highly probable that the United Kingdom will continue to play a pivotal role in the advancement and utilisation of military robotic systems.

[493] Ball, Mike. Extra-Large UUV to be Developed for UK Royal Navy, *Unmanned Systems Technology*, https://www.unmannedsystemstechnology.com/2020/03/extra-large-uuv-to-be-developed-for-uk-royal-navy/, 9 March 2020. (Accessed on 09.09.2022)
[494] £15.4 million contract for first cutting-edge Navy crewless submarine, *UK Ministry of Defence*, https://www.gov.uk/government/news/154-million-contract-for-first-cutting-edge-navy-crewless-submarine, 1 December 2022. (Accessed on 02.11.2022)

France

With the creation of the Defence Innovation Agency (Agence Innovation Défense, AID) in 2018, France largely reformed its defence innovation system. According to Emmanuel Chiva, the Director of the AID, *"(…) the AID is in charge of orientating the innovation policy – which is chaired by a Defence Innovation Committee – but also of detecting, experimenting and adapting the innovation to be able in the end, both to accelerate and deploy it."*[495] The creation of the AID *"(…) shifted the organisation of innovation-related activities from programmes to capabilities and introduced more agility."*[496] The AID, as a new branch of the General Delegation for Armament (Délégation Générale pour l'Armement, DGA) reflects a deep evolution among France's strategic planning, specifically that in order to keep an edge on the battlefield, France aims to invest in coupling its private sector with its world-class defence industry. The fact that the Military Programming Law (Loi de Programmation Militaire 2019-2024, LPM) increased the AID's budget from EUR 720 million to 1 billion is a telling illustration of this process.[497] This push to develop innovation in the field of defence relies on France's realisation of a changing international environment and relies on three pillars: (1) strategic autonomy made possible by Paris' nuclear deterrent and effective armed forces, (2) European cohesion in the coming age of increased competition between great powers, notably focused on strengthening the Franco-German duo within the EU and, (3) stable transatlantic relations while seeking to diminish the continent's reliance on US hard power.[498] A recent document stressed the importance of NATO for France and described the doubling of the military budget over the period 2019-2039 (LPM 2024-2030).[499]

The primary aim of the AID is to provide guidance and information pertaining to defence procurement. Its purpose is to effectively identify and incorporate commercial innovations that align with military requirements, while also expediting and implementing defence innovation through novel procurement, contracting, and acquisition frameworks.[500] The AID is therefore an institution that completes a whole set of tasks, that would be achieved by different institutions in other countries. These objectives are stated in multiple French official documents, the first among which is the Strategic Vision of the Chief of the Defence Staff (*Vision Stratégique du Chef d'Etat-Major des Armées): "Innovation must be able to maintain conceptual, organisational and technological superiority. This requires mobilising all defence innovation players in the service of the armed forces' purpose, the operational commitment."*[501] The primary objective of the AID is to capture innovation at its inception, specifically targeting ambitious dual-use technologies and projects before they materialise into prototypes. In order to achieve this goal, the AID has established the RAPID system, which is designed to provide financial and material support, such as access to laboratories, to facilitate the development of ambitious projects with significant potential for defense-related applications.[502] According to certain experts, the creation of AID is truly revolutionary because it is disrupting traditional

[495] Chiva, Emmanuel., "All the threats come together at the Defence Innovation Agency", *European Defence Matters*, Issue 22, 2021.: 18.
[496] Merindol, Valérie and Versailles, David. "The (R)evolution of Defence Innovation Models", *Armaments Industry European Research Group (ARES)*, 2020.: 15.
[497] Document de Référence de l'Orientation de l'Innovation de Défense, *Ministère des Armées*, 2022.: 67.
[498] Duclos, Michel. Guerre en Ukraine : Nouvelle politique étrangère pour la France, *Institut Montaigne*, https://www.institutmontaigne.org/publications/guerre-en-ukraine-nouvelle-politique-etrangere-pour-la-france, June 2022. (Accessed on 12.09.2022)
[499] Revue Nationale Stratégique 2022 (RNS), *Secrétariat Général de la Défense et de la Sécurité Nationale (SGDSN)*, 2022.
[500] Pothier, Fabrice and Chiva, Emmanuel. A French perspective on defence innovation, *International Institute for Strategic Studies (IISS)*, https://www.iiss.org/events/2021/04/defence-innovation-french-perspective, 2021. (Accessed on 26.09.2022)
[501] Général Burkhardt, Vision Stratégique du Chef d'Etat-Major des Armées, *Ministère des Armées*, 2021.: 16.
[502] Document de Référence de l'Orientation de l'Innovation de Défense, *Ministère des Armées*, 2022.: 35.

French military culture: *"The French MOD's support to innovation imposes a real change in the management of weapon system programmes, particularly when considering the risks and the programme's architecture and organisation. This change of mindset and procedures is moving slowly due to financial habits (defence processes do not include investment return considerations), promotion processes (major programme management is the key to high-level positions) and regulation constraints (aeronautics norms, nuclear regulations, etc.)."*[503]

The Innovation Defence Fund (Fonds Innovation Défense, FID) provides pecuniary support to various actors working in the field of technology, such as universities, laboratories, start-ups, and SMEs. Figure 17 shows that the French government spent EURO 1.3 billion on defence-related R&D in 2020. According to data from Figure 18, France has a vast ecosystem of ATITCs composed of civilian research centres, academic institutions, and private research institutes (15 overall, 3 focused on robotics and 8 on AI). This ecosystem represents a comparative advantage for France over other European states and has been identified by the French authorities as a valuable source of innovation for the defence sector. Linking these centres with the private sector is exactly what FID aims at doing, therefore providing for effective public-private partnerships. The Ministry of Armed Forces (Ministère des Armées, MdA or MoD) contributed EUR 200 million to FID, while private funds raised another 400 million. Project Centurion, an accelerator of defence-related innovation, represents another significant tool devised by the French authorities. Its primary objective is to facilitate the expeditious progress of developers' projects by providing them with the invaluable expertise of scientists and project managers.[504]

The optimisation of France's exceptional defence industry and innovation capabilities has been a longstanding goal of the French government, as evidenced by the reform of the DGA in 2018 under the leadership of former Minister of the armed forces, Florence Parly. This reform aimed to streamline acquisition procedures, expedite technology transfer, and prioritise the armed forces' needs above all else.[505] According to an official document, *"The success of scaling up, integrating (…) the innovation stemming from technological evolutions in the civilian world, or from operations, is today an imperious necessity. The logic of continuous improvement* [infusing] *the new armament programmes renders this possible and puts innovation at the tip of the spear."*[506] In terms of the second, third and fourth factors influencing innovation, we can say that France is strongly driven by them, given that it has recently processed: (1) a convergence between military and political objectives to foster innovation, (2) a reform of the defence-related innovation governance and, (3) a growing investment in this field by both public and private actors.

With regards to testing, the French armed forces run several laboratories, such as the Innovation Défense Lab, across the country.[507] As France currently develops military robotics for all domains, *"The French Innovation Agency and its Defence lab will develop complementarities and networked activities with these labs in the future."*[508] The AID and MdA have allocated significant resources to establish a domestic network of partner institutions with the aim of enhancing, progressing, and maintaining defence-related innovation. However, the

[503] Devaux, Jean-Pierre and Schnitzler, Gaspard. "Defence Innovation: New Models and Procurement Implications: The French Case", *Armaments Industry European Research Group (ARES),* 2020.: 8.
[504] *Ibid*.: 44.
[505] Hartley, Keith, and Belin, Jean*. The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 158.
[506] Defence Innovation Orientation Directive - 2020 Activity Report, *Ministère des Armées*, 2021.: 31.
[507] Merindol, Valérie and Versailles, David. "The (R)evolution of Defence Innovation Models", *Armaments Industry European Research Group (ARES),* 2020.: 12.
[508] *Ibid.*: 12.

most prominent endeavour has been focused on fostering international collaboration. France, in its pursuit of fortifying not only its own strategic position but also that of Europe, has actively participated in numerous military innovation initiatives at both European and international levels. Hence, the *Document de Référence de l'Orientation de l'Innovation de Défense* (DrOID), AID's document of reference, highlights that cooperation with HEDI and NATO DIANA are at the centre of France military innovation strategy.[509] Additionally, France aims at improving its effort in bilateral agreements with partners such as the US, Canada, the Netherlands, Singapore and the UK. France seeks more partnerships, being currently leading projects with Germany and Spain on the Future Combat Air System (FCAS) and Main Ground Combat System (MGCS).[510]

Overall, the AID's objective is to guide and inform defence procurement, to identify and adopt commercial innovations to meet military needs, and to accelerate and deploy defence innovation through new procurement, contracting and acquisition structures.

France, being a prominent European military power, exhibits a keen interest in the advancement of military robotic systems with the objective of enhancing its combat capabilities. Notably, France stands out as one of the few nations that has released an official artificial intelligence (AI) strategy pertaining to defence matters. However, it is worth noting that the aforementioned strategy document does not explicitly delve into the realm of military robotics.[511] Overall, the French army is looking for robotic systems that can relieve the soldiers' burden and enhance the combat awareness of platoons and companies.[512] This vision was described by General Burkhard, the French Chief of Staff, during a military exercise in 2021 that saw the use of three UGVs alongside an infantry unit. The so-called *Projet Vulcain* aims at decreasing the risk for soldiers by using military robots to complete ISR and attack purposes.[513] UAVs and UGVs will be developed to support and complete other manned systems, as it is planned for FCAS and MGCS. France is currently developing the Project Scorpion, designed as *"(…) the digital backbone connecting a fleet of vehicles to create what the French Ministry of Defence called a platform for 'collaborative combat'. It is designed to automatically distribute alerts, targeting information and a host of other data between vehicles, robots and UAVS, with the aim of optimising fire support and safety."*[514] *The Projet Scorpion* represents a pioneering and progressive endeavour aimed at integrating novel technologies in the domain of air-land warfare, including augmented systems, robotics, and collaborative combat, within a centralised framework (see Figure 20 below).

In the longer term (2035-2040), *Projet Titan* aims to emulate *Projet Scorpion*, by integrating new systems (notably in the heavy segment, with the successor to the Leclerc tank, the

509 Document de Référence de l'Orientation de l'Innovation de Défense, *Ministère des Armées*, 2022.: 59.
510 Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften» Attn.: Swiss Drone and Robotics Centre (SDRC DDPS)", *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022. Factsheet: France. : 1.
511 Intelligence Artificielle au Service de de la Défense, *Ministère des Armées*, 2019.
512 Document de Référence de l'Orientation de l'Innovation de Défense, *Ministère des Armées*, 2022. : 8.
513 Samama, Pascal. L'Armée de Terre dévoile la section Vulcain, l'unité de robots qui sera opérationnelle en 2030, *Association de Soutien de l'Armée Française (ASAF)*, https://www.asafrance.fr/item/equipement-l-armee-de-terre-devoile-la-section-vulcain-l-unite-de-robots-qui-sera-operationnelle-en-2030.html, 14 June 2021. (Accessed on 13.09.2022)
514 Lye, Harry. Scorpion: France's collaborative combat platform in action, *Army Technology*, https://www.army-technology.com/features/scorpion-frances-collaborative-combat-platform-in-action/, 19 March 2020. (Accessed on 26.04.2023)

MGCS) as well as by increasing the collaborative architecture at the joint and allied levels.[515] These programs aim at resolving a longstanding and pivotal predicament faced by the French armed forces: the quest for achieving an optimal equilibrium between a proficient and technologically advanced military force with limited personnel, and a larger, albeit less sophisticated, army capable of withstanding attrition.[516] In addition, the Future Combat Command (Commandement du Combat du Futur, CCF), which was created in August 2023 is currently being set up, is the major body responsible for the coherence of the army's capabilities and doctrine, and for developing its capacity for innovation.[517] An article published in the *Franc-Tireur Terre* magazine divides the prospective potential uses of UGVs in French land forces into defensive and offensive categories. Defensive missions include (1) protection of logistical bases, (2) securing the rear of large units, and (3) observation in non-priority areas. Offensive missions for UGVs include: (1) harassing enemy units, (2) disorganising enemy forces, (3) creating a diversion, (4) creating deceptions and operational feints, and (5) breaking through defensive lines.[518]

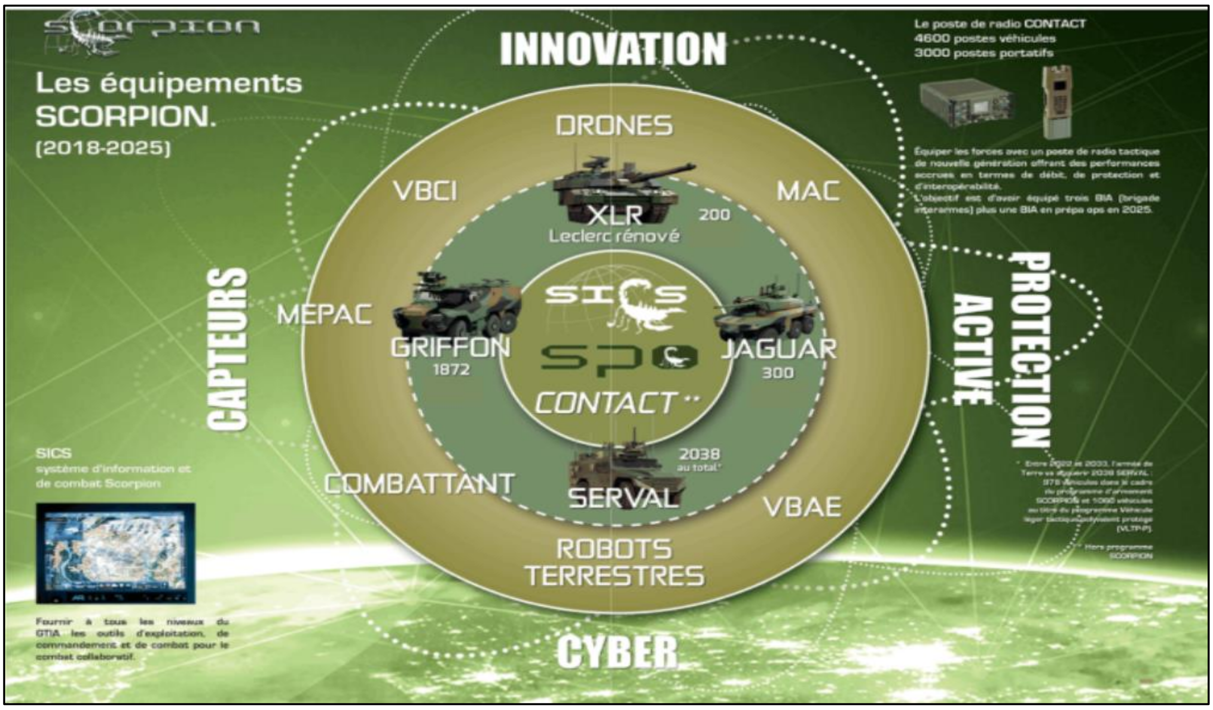

Figure 20 - France's "Système d'Information et de Combat Scorpion" (SICS).[519]

[515] Doitier, Martin. Titan : le projet capacitaire de l'armée de Terre structurant les quinze années à venir, *Areion 24*, https://www.areion24.news/2020/09/22/titan-le-projet-capacitaire-de-larmee-de-terre-structurant-les-quinze-annees-a-venir/, 22 September 2020. (Accessed on 26.04.2023)
[516] Shurkin, Michael. Why The French Army Will Continue to Prioritize Quality over Mass, *War on the Rocks*, https://warontherocks.com/2023/04/why-the-french-army-will-continue-to-prioritize-quality-over-mass/, 28 April 2023. (Accessed on 29.04.2023)
[517] Face aux nouvelles réalités opérationnelles, l'Armée de Terre renforce l'innovation, *Institut des Hautes Etudes de Défense Nationale (IHEDN)*, https://ihedn.fr/2023/10/16/face-aux-nouvelles-realites-operationnelles-larmee-de-terre-renforce-linnovation/. (Accessed on 17.10.2023)
[518] Buchard-Joubert, Aurélien. "Etude prospective sur l'emploi des robots terrestres à l'horizon 2050 : vers l'apparition d'un concept de dissuasion conventionnelle", Le Franc-Tireur Terre #02-2023, La Revue de l'Ecole de Guerre-Terre, *Ministère des Armées*.: 75-76.
[519] Le programme Scorpion, *Ministère des Armées*, https://www.defense.gouv.fr/terre/nos-materiels-nos-innovations/nos-innovations/dossier-programme-scorpion/programme-scorpion. (Accessed on 26.04.2023)

Taken altogether, the French military robotics market will likely grow by a CAGR of 21.02% over the 2020-2025 period. Similarly to the UK, France has been investing more resources in UAVs than in any other type of robotics. In 2019, the UAVs market in France already represented USD 109 million, and it is expected to almost triple in size by 2025, reaching USD 305 million. This is a legacy of France's leadership in the development of drones for almost three decades, as was the case with Dassault's Eurodrone. Parallelly, France purchased at least 24 MQ-9 Reaper drones from the US as of 2022.[520] The French air force and navy are in the process of renewing their fleet of embarked rotor- and fixed-wing aircrafts and intend to use several types of UAVs to do so. The first type is the VSR700 helicopter developed by Airbus as part of the Naval Airborne Drone System (Système de Drone Aérien de la Marine*,* SDAM), a platform that can conduct almost all types of missions, from ISTAR to ASW, and logistical support.[521] The second type is named Aliaca and is part of the Naval Mini-Drone System (Système de Mini-Drone embarqué de la Marine*,* SMDM). The French navy is ambitious about the potential of using drones to complete its missions, as Admiral Prazuck stated that the Marine Nationale should count 1'200 UAVs of all types by 2030.[522] The French army is presently advancing compact combat drones, like the AVATAR, which can accommodate an HK-416 F firearm.[523]

Platforms	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	109	134	152	177	222	258	305	17.9%
UGVs	41	41	50	62	83	103	129	25.7%
UMSs	-	-	2.3	5	9	14	21	77%
Total	**150**	**175**	**204.3**	**244**	**314**	**375**	**455**	**20.6%**

Figure 21 - France military robotic and autonomous systems market, USD million.[524]

The UGVs market in France is also rapidly expanding. It is expected to grow more rapidly, to account for USD 129 million in 2025. France is not a pioneer in this field.[525] Remarkable UGVs systems developed in France include the Cameleon LG E and NERVA, both light anti-EOD devices, as well as the ULTRO and PROBOT "mule" carriers.[526] Defence industry leader

[520] Tanguy, Jean-Marc. French Armed Forces Ministry details UAV roadmap, *Janes,* https://www.janes.com/defence-news/news-detail/french-armed-forces-ministry-details-uav-roadmap, 21 June 2021. (Accessed on 13.09.2022)
[521] Vavasseur, Xavier. France Speeds Up UAV Procurement For French Navy As Part Of Industry Recovery Plan, *Naval News*, https://www.navalnews.com/naval-news/2020/06/france-speeds-up-uav-procurement-for-french-navy-as-part-of-industry-recovery-plan/, 9 June 2020. (Accessed on 13.09.2022)
[522] *Ibid.*
[523] Face aux nouvelles réalités opérationnelles, l'Armée de Terre renforce l'innovation, *Institut des Hautes Etudes de Défense Nationale (IHEDN)*, https://ihedn.fr/2023/10/16/face-aux-nouvelles-realites-operationnelles-larmee-de-terre-renforce-linnovation/. (Accessed on 17.10.2023)
[524] Figure made by the authors. *Source:* Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 165.
[525] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften» Attn.: Swiss Drone and Robotics Centre (SDRC DDPS)"; *Center for Security Studies (CSS),* ETH Zürich (ed.), 2022. Factsheet: France 2.
[526] Danish army tests the French ULTRO 4x4 UGV Unmanned Ground Vehicle from Nexter, *Defense News*, https://www.armyrecognition.com/defense_news_january_2022_global_security_army_industry/danish_army_tests_the_french_ultro_4x4_ugv_unmanned_ground_vehicle_from_nexter.html, 6 January 2022. (Accessed on 13.09.2022) ; Face aux nouvelles réalités opérationnelles, l'Armée de Terre renforce l'innovation, *Institut des Hautes Etudes de Défense Nationale (IHEDN)*, https://ihedn.fr/2023/10/16/face-aux-nouvelles-realites-operationnelles-larmee-de-terre-renforce-linnovation/. (Accessed on 17.10.2023)

Nexter and specialised company SERA Ingénierie recently signed a partnership to develop UGV capabilities for France's ground forces, such as the PHOBOS, a multipurpose system for combat engineers.[527] The UMSs field is considerably smaller for France, but it is also the market that is likely to develop the most by 2025. Virtually no investment was made in UUVs/USVs in 2019 and this market will reach 21 million in 2025. The French navy is fielding the D-19 UUV produced by Naval Group and will use it for a whole spectrum of missions: ISR, electronic warfare and anti-mine warfare.[528] Regarding USVs, France has multiplied its efforts in recent years, notably by using multilateral cooperation through PESCO and EDA. Alongside Estonia and Latvia, France is developing the Medium USV or MUSV, a boat that can be manned or unmanned depending on the degree of danger of the mission. In 2022, the French Navy unveiled a Seabed Warfare Strategy envisioning the active use of ROVs and AUVs to monitor the seabed to depths down to 6'000 meters.[529]

[527] Nexter et SERA Ingénierie (SOGECLAIR) s'allient pour former le champion français de la robotique militaire, *Nexter Group*, https://www.nexter-group.fr/actualites/nos-dernieres-actualites/nexter-et-sera-ingenierie-sogeclair-sallient-pour-former-le, 4 April 2023. (Accessed on 11.04.2023)
[528] Vavasseur, Xavier. Euronaval: French Navy Becomes Launch Customer of Naval Group's D-19T UUV, *Naval News*, https://www.navalnews.com/event-news/euronaval-2020/2020/10/euronaval-french-navy-becomes-launch-customer-of-naval-groups-d-19t-uuv/, 21 October 2020. (Accessed on 14.09.2022)
[529] Vavasseur, Xavier. France Unveils New Seabed Warfare Strategy, *Naval News*, https://www.navalnews.com/naval-news/2022/02/france-unveils-new-seabed-warfare-strategy/, 16 February 2022. (Accessed on 08.05.2023)

Germany

In contrast to the United Kingdom and France, which are the predominant military powers in Europe, Germany has exhibited a comparatively slow response in adjusting its defense-related ecosystem to effectively address EDTs. This can be attributed to Germany's historical background and prevalent pacifistic tendencies, which have shaped the discourse surrounding defence and the use of force. Consequently, the deliberations in Germany predominantly revolve around moral considerations rather than interests and a pragmatic comprehension of the global order.[530] This explains largely Berlin's choice to rely almost entirely on NATO's – and therefore US' – hard power to ensure its security and on the EU to advance its political agenda. At the level of military innovation, the German posture also explains the existence of *"(…) a deliberate 'firewall' between civilian and defence research as well as traditional concern in society and parts of the political landscape over defence and dual-use research."*[531] The most important institution in charge of monitoring defence-related innovation is the Division I of the German Armed Forces – Goal Setting and Innovation (Abteilung I der Bundeswehr, Zielbildung und Innovation, PlgABwI), which evaluates the importance of new technologies in the field of defence, incubates and supports defence-related innovation for the German armed forces.[532] The Office of the Army Development (Amt für Heeresentwicklung, AfH*)* is the institution within the Armed Forces that is developing, integrating, and fielding new capabilities such as AI and military robotics.[533]

In light of Germany's federal system, it is unsurprising that multiple organisations undertake tasks that would typically be consolidated under a single entity in a country like France. This fragmentation poses a hindrance to the collective innovation endeavour. Importantly, Germany has recently reassessed its strategic environment, in the wake of Russia's aggression of Ukraine. Berlin announced EURO 100 billion worth of investment in the military over several years, marking what observers have depicted as a "Zeitenwende" (turn or times, in English).[534] In 2022, political representatives have taken positions that would have been unimaginable just a few months earlier, such as that the Bundeswehr must become Europe's leading army in the near future in terms of its capabilities and equipment.[535] The initial catalyst for fostering innovation within the military domain, namely the perception of geopolitical threat, can be characterised as undergoing substantial transformations in Germany.[536]

Innovation in the military domain has long been highlighted as one of the most important features of the Bundeswehr's development, as Germany's 2016 Whitebook notes that *"(…) technological innovation is the key to securing the future."*[537] EDTs are considered of primary importance as the PlgABwI has recently set up the Strategic Foresight (*Strategisch*

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[530] Giegerich, Bastian, and Terhalle, Maximilian. *The Responsibility to Defend: Rethinking Germany's Strategic Culture*. Adelphi 477. Abingdon, Oxon: Routledge, 2021.: 27.
[531] Mölling, Christian and Schütz, Torben. "Defence Innovation: New Models and Procurement Implications. The German Case", *Armament Industry European Research Group (ARES)*, 2021.: 7.
[532] Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.
[533] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften»" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS); *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022: Factsheet: Germany.: 2.
[534] Kroenig, Nicole. "The Zeitenwende: Germany's Reluctant Revolution", *American Institute for Contemporary German Studies* at John Hopkins University, https://www.aicgs.org/publication/the-zeitenwende-germanys-reluctant-revolution/, 6 July 2022. (Accessed on 15.09.2022)
[535] Lindner plant Sondervermögen – Bundeswehr soll "schlagkräftigste Armee Europas" werden, *N-TV*, https://www.n-tv.de/politik/Bundeswehr-soll-schlagkraeftigste-Armee-Europas-werden-article23160774.html, 28 February 2023. (Accessed on 03.07.2023)
[536] National Security Strategy – Integrated Security for Germany, *Federal Foreign Office*, June 2023.: 22.
[537] Weissbuch 2016: Zur Sicherheitspolitik und zur Zukunft der Bundeswehr, *Bundesregierung*, https://www.bmvg.de/resource/blob/13708/015be272f8c0098f1537a491676bfc31/weissbuch2016-barrierefrei-data.pdf, 2016. (Accessed on 16.09.2022)

Vorausschau), a team of officers, political scientists and fiction writers to imagine potential scenarios for future conflicts and assist military planners to prepare the Bundeswehr accordingly.[538] Intensive integration between the civilian and defence industries is also deemed essential, notably for R&D.[539] The German defence expenditures in R&D ranged between EUR 1.1 and 1.55 billion in 2020, among which 512.5 million are reserved for defence research and technology and 380.1 for defence development and testing. This substantial allocation of funds by the government, however, disregards the prevailing reality in Germany, where approximately 95% of R&D expenses incurred by the German defence sector are derived from state funding. Consequently, only a limited number of projects receive financial backing or impetus from private enterprises.[540]

Particularly important in the defence innovation ecosystem are state-funded research centres such as the Fraunhofer Group for Defence and Security, the Army Technical Universities at Munich, and Hamburg (Wehrtechnische Dienststellen) and private defence companies such as Rheinmetall.[541] In Germany, a distinctive characteristic is the deliberate choice made by a considerable number of academic institutions to abstain from engaging in R&D activities related to dual-use technologies, which possess the potential for weapon development. Termed as the "firewall," this approach accurately reflects the distinct demarcation between civilian and military domains within German society. This stance hampers the nation's endeavours to foster substantial advancements in the realm of defence innovation.[542] As Figure 18 indicates, Germany has 14 ATITCs on robotics/human-machine interference and seven on AI. Despite these high numbers, Germany remains restrained on further accelerating defence-related R&D efforts. In order to assess Germany's position in relation to the second, third, and fourth factors influencing innovation, several dynamics can be discerned. (1) there is an increasing recognition of the strategic significance of innovation; (2) the reform of the innovation governance system is still in progress, albeit incomplete; (3) the collaboration between private entities and government agencies is inadequate due to the existence of a so-called "firewall," despite substantial government funding.

The German authorities have launched different initiatives to stimulate their country's defence-related R&D capabilities. Two institutions emerged in 2020: the Cyber Innovation Hub (CIH) and the Centre for Digitalisation and Technology Research (CDTR). These two organisations are start-up incubators aiming at facilitating links between private tech firms and the armed forces' needs.[543] Such steps forward are significant but probably unable to counter a major weakness of the German military innovation ecosystem: the fact that it is mainly composed of SMEs across the whole supply chain. Indeed, besides a handful of giant companies, such as Rheinmetall, Airbus or ThyssenKrupp, most German companies working in the field of defence are relatively small companies with few capacities to sustain projects and intense investments over the long term. Therefore, it makes it very difficult for institutions such as the PlgABwI to gather different SMEs across several sectors to design ambitious innovation projects.[544]

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[538] Autorenteam der Abteilung I des Planungsamtes der Bundeswehr, Das Planungsamt der Bundeswehr - Zielbildung und Innovation, *Sonderheft (WT)*, 2021.: 11

[539] "Future Operating Environment (FOE) 2040", Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), *Bundeswehr*, 2023.: 99.

[540] Mölling, Christian and Schütz, Torben. "Defence Innovation: New Models and Procurement Implications. The German Case", *Armament Industry European Research Group (ARES)*, 2021.: 7.

[541] Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.

[542] Mölling, Christian and Schütz, Torben. "Defence Innovation: New Models and Procurement Implications. The German Case", *Armament Industry European Research Group (ARES)*, 2021.: 7.

[543] *Ibid.:* 10.

[544] Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.

This is a major difference between Germany and the UK, for example, and is largely the result of Berlin's little effort to arm itself in the second half of the 20th century and to disarm in the wake of the *Wiedervereinigung*.[545] This is also the consequence of Berlin's vaguely defined industrial defence policy, which stems from the fact that it never accurately listed which sector it considered a core capacity to protect.[546] Such a weakness impedes Germany's overall innovation capability: *"Both single-domain structure as well as small size hamper the ability of these actors to independently invest in R&D and inhibits cross-domain technological innovation within companies."*[547] Germany faces a significant predicament concerning the protracted duration and bureaucratic intricacies associated with capability identification and procurement procedures, as depicted in Figure 22. This further participates to disengage firms active in the defence sector.[548]

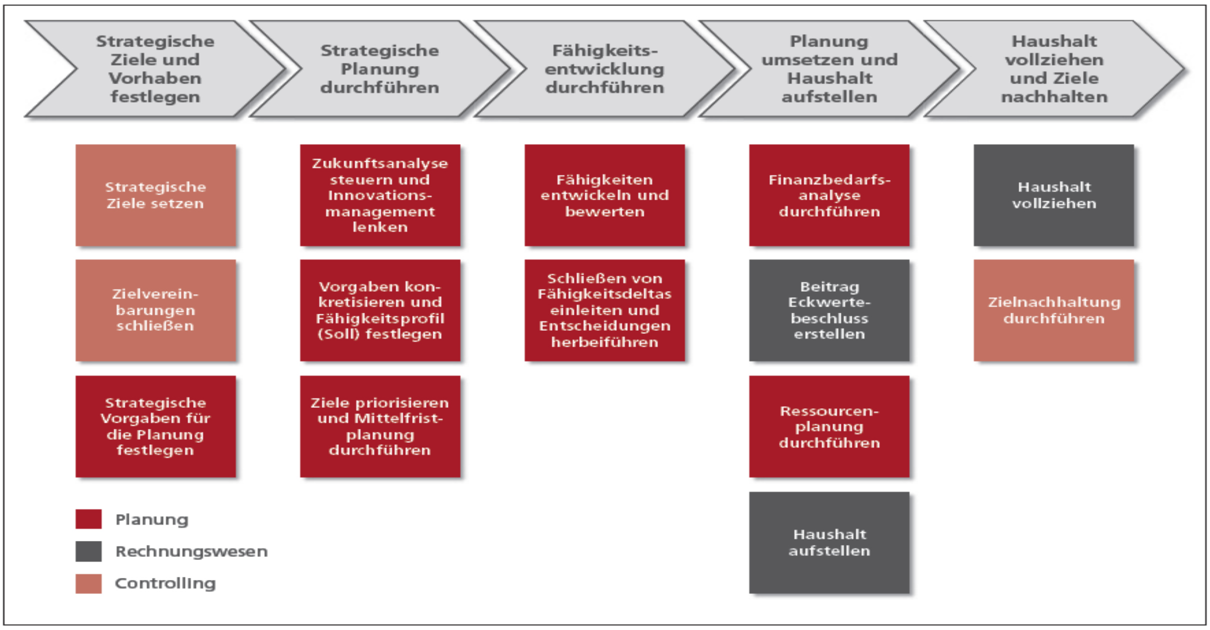

Figure 22 - The Bundeswehr's integrated capability development and procurement processes.[549]

Germany's involvement in bilateral and European collaborations is expected to enhance its position in defense-related innovation. Notably, Germany and the UK are actively engaging at the highest political level to identify opportunities for the development of joint research programs focused on UAVs.[550] The same goes for cooperation in military innovation between Berlin and Paris, with the establishment of the French-German Research Institute of Saint-Louis (ISL). At the EU level, Germany is one of the most active actors in defence-related innovation, having actively supported the establishment of PESCO, EDF, EDA, HEDI, etc.[551]

[545] Laird, Robb. Germany, Its Military and Shaping a Way Ahead: Strategic Focus, Allies and Creation of an Appropriate Force Structure, *Defense Info,* https://defense.info/re-thinking-strategy/2018/12/germany-its-military-and-shaping-a-way-ahead-strategic-focus-allies-and-creation-of-an-appropriate-force-structure/, 12 November 2018. (Accessed on 15.09.2022)
[546] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 195.
[547] Mölling, Christian and Schütz, Torben. "Defence Innovation: New Models and Procurement Implications. The German Case", *Armament Industry European Research Group (ARES)*, 2021.: 9-10.
[548] Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.
[549] Czernik, Ingolf. "Integrierte Planung in der Bundeswehr – ein Instrument, zwei Sichten", *CPM*, 2021.: 30.
[550] Becker, Sophia et al. "Learning Together: UK-Germany cooperation on military innovation and the future of warfare", *The Policy Institute at King's College London*, November 2020.: 6.
[551] Mölling, Christian and Schütz, Torben. "Defence Innovation: New Models and Procurement Implications. The German Case", *Armament Industry European Research Group (ARES)*, 2021.: 12.

Germany also views the progress of NATO initiatives favourably and does not perceive the overlaps and competition between specific tools of the EU and NATO as inherently negative.[552] However, the absence of a comprehensive approach towards defence-related innovation in Berlin undermines its strategic significance and discourages partners from relying on Germany's leadership in matters pertaining to defence.

Robotics is a field that is not currently prioritised in Germany. Illustratively, the fourteen *Procurement Reports* (Rüstungsberichte) do not mention RAS projects apart from the Eurodrone.[553] Even the *German Armed Forces' Research Report* (Wehrwissenschaftliche Forschung für deutsche Streitkräfte) only mentions robotics twice, while no German research project on robotics is cited.[554] An official document that revolves around this topic of doctrine can be found on the *AfH Position Paper on AI in the Army* (Künstliche Intelligenz in den Landstreitkräften), but it only stipulates that the Bundeswehr will not field LAWS.[555] In addition, this paper does not fit the overall national strategy of Germany, which makes no mention of autonomous systems or military AI.[556] Parallelly, the debate on unmanned systems was addressed by the German MoD and gave birth to a protocol for the engagement of UAVs in the German armed forces, compiling 15 articles that define the legal framework, the RoE, the order structure and the formation that must be implemented.[557] Importantly, armed UAVs are to be used solely to defend German soldiers and military assets.[558] Regarding UUVs, a research paper by PlgABwI precised that the Germany Navy will only use such systems if they perform *"(…) at least as well or better than manned systems."*[559] Military applications envisioned for UUVs include ASW, MCM, ISR, communication disturbance and direct combat role.

The matter concerning the incorporation and deployment of unmanned systems and robots within the military is not regarded as a doctrinal matter. In discussions with esteemed German military officials, this matter has consistently been characterised as being closely associated with "Grundeinsatzprinzipen" (basic operational principles).[560] This phrasing underscores the limited progress made in Germany regarding the contemplation of incorporating and employing these systems within an operational framework. Nevertheless, the geopolitical circumstances, Germany's perception of threats, and advancements in technology appear to be propelling the integration and use of military robotics. Recently, a prospective document on the future of armed conflicts detailed several advantages specific to the use of robotic systems: *"Armed forces exploit tactical advantages of MR solutions (e.g. reaction speed in*

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552 Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.

553 Süssmuth, Sandra. Die Eudodrone ist auf dem Weg, *Bundeswehr*, https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/die-eurodrohne-ist-auf-dem-weg-5044732, 24 March 2021. (Accessed on 19.10.2022)

554 Wehrwissenschaftliche Forschung Jahresbericht 2020. Wehrwissenschaftliche Forschung für deutsche Streitkräfte, *Bundesministerium der Verteidigung*, 2021.

555 Künstliche Intelligence in den Landstreitkräfte, *Amt für Heeresentwicklung – Bundeswehr*, October 2019.: 7.

556 Francke, Ulrike. "Not Smart Enough: The Poverty of European Military Thinking on Artificial Intelligence", *European Council on Foreign Affairs (ECFR)*, 2019.: 15-16.

557 Bericht des Bundesministeriums der Verteidigung an den Deutschen Bundestag zur Debatte über eine mögliche Beschaffung bewaffneter Drohnen für die Bundeswehr, *Bundesministerium der Verteidigung*, 2020.: 19.

558 Gady, Franz-Stefan and Glaese, Oskar. Germany to operate armed UAVs: too little too late?, *International Institute for Strategic Studies (IISS)*, https://www.iiss.org/blogs/analysis/2021/11/germany-to-operate-armed-uavs-too-little-too-late, 21 November 2021. (Accessed on 16.09.2022)

559 "Future Topic – Unmanned Underwater Vehicles, Sachstand und Perspektiven für Militarische Unterwasserwirkmittel", Planungsamt der Bundeswehr, *Zukunftanalyse*, 2017.: 17.

560 Interview at the Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), 27 May 2023.

duel situations; balance between human operators and MR substitutes; OODA loop integration).”[561] Figure 23 describes the size of the market for each type of unmanned system.

The German military robotics market is expected to grow by a CAGR of 25.01% over the 2020-2025 period, which is a little more than France and the UK. As shown in Table 7, the Bundeswehr has been operating a significant number of UAVs during the last two decades, including RQ-20B Puma AE II, Heron and nationally produced models. This is illustrated by the size of the UAV market in Germany, expected to grow from EUR 159 million in 2019 to 492 million in 2025. This dynamic is picking up steam as Olaf Scholz' government has endorsed the arming of UAVs into its coalition agreement, paving the way for new developments in this field. Germany has signed a contract with IAI to purchase five additional Heron MALE UAVs and plans to arm them with air-to-ground precision munitions.[562] Germany will also acquire the drone MQ-4C Triton, produced by the American firm Northrop Grumman. However, despite these acquisitions, it remains a fact that Germany is presently falling behind in terms of effectively incorporating UAVs into its comprehensive military planning: *“It also meant that the armed forces have built up no experience in armed UAV operation to help inform decision-making and planning.”*[563] In addition, Germany is currently developing Vertical Take-Off and Landing (VTOL) UAVs for its navy with France. Berlin is also leading an EDA program, the Open Cooperation for European Maritime Access (OCEAN), aiming for collaboration of European states in the design of embarked UAVs for the maritime domain.[564] In the field of mini-drones, Germany has recently procured its land forces with the ASUL C-UAS system or Guardion to help soldiers on the ground to identify, locate and engage threatening drones.[565]

Platforms	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	159	181	214	258	335	402	492	22.1%
UGVs	13	17	22	31	47	63	87	38%
UMSs	-	-	3.4	6	11	18	27	68%
Total	**172**	**198**	**239.4**	**295**	**393**	**483**	**606**	**23.4%**

Figure 23 - Germany military robotic and autonomous systems market, USD million.[566]

In the field of UGVs, Germany's market is relatively small in comparison to France and the UK. Yet, it is expected to grow very importantly by 2025, from EUR 13 million in 2019 to 87 million by 2025. The German firm Rheinmetall has developed the Mission Master UGV, a multi-purpose wheeled platform that exists in three variations: cargo module, fire support

[561] “Future Operating Environment (FOE) 2040”, Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), *Bundeswehr*, 2023.: 43. Translation by the authors.
[562] Gady, Franz-Stefan and Glaese, Oskar. Germany to operate armed UAVs: too little too late?, *International Institute for Strategic Studies (IISS)*, https://www.iiss.org/blogs/analysis/2021/11/germany-to-operate-armed-uavs-too-little-too-late, 21 November 2021. (Accessed on 16.09.2022)
[563] *Ibid.*
[564] Tilenni, Giulia. European UAV/UAS Requirements, *European Security & Defence*, https://euro-sd.com/2020/07/articles/18205/european-uav-uas-requirements/, 26 July 2020. (Accessed on 15.09.2022)
[565] Camargos Pereira, Flavia. Germany introduces ASUL C-UAS system for field protection, *Shephard Media*, https://tinyurl.com/bdd6f474, 25 August 2022. (Accessed on 17.09.2022)
[566] Figure made by the authors. *Source:* Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 167.

module and rescue module. These different modules are to be operated simultaneously and with a machine-human teaming to offer the best results, something Rheinmetall calls the “Wolf Pack”.[567] The UMSs market is still young in Germany, which is logical given the country’s land power tradition and relatively small navy in comparison to its land forces. We can nevertheless highlight the important growth that is forecasted for this field. If the German UUVs/USVs market reaches EUR 27 million by 2025, it will become larger than the French market, which marks the increasing significance of this domain for Berlin. As of now, Germany has successfully integrated a batch of REMUS 100 UUVs, tasked with counter-mine measures, to its navy.[568] The German firm Siemens is currently working on an innovative technology to power UUVs called Polymer Electrolyte Membrane (PEM) using the molecules composing water – oxygen and hydrogen – to propel hulls.[569]

[567] Germany’s Rheinmetall introduces unmanned ground vehicle with 7.62 mm RCWS, *Defense Brief*, https://defbrief.com/2020/11/24/germanys-rheinmetall-introduces-unmanned-ground-vehicle-with-7-62-mm-rcws/, 24 November 2020. (Accessed 17.09.2022)
[568] HII Delivers REMUS 100 UUVs To The German Navy, *Naval News,* https://www.navalnews.com/naval-news/2020/12/hii-delivers-remus-100-uuvs-to-the-german-navy/, 21 December 2022. (Accessed on 17.09.2022)
[569] Wise, Dan. How do You Power the Navy’s Next Generation of Unmanned Undersea Vehicles (UUVs)? The Answer is in the Water*, Siemens*, https://tinyurl.com/2endd7h5, 7 November 2018. (Accessed on 20.09.2022)

Italy

In terms of threat and vulnerability perceptions, the first driver of innovation, Italy is reassessing its position in a changing international environment. Having long sought good relations with both the West and the East, Rome is waking up to what former Prime Minister Conte called *"(…) a naïve foreign policy"* with regard to China's economic coercion of EU states.[570] The same goes for Italy's long-lasting and strong relationship with Moscow, which has unravelled since February 24th, 2022.[571] The Meloni government's extensive and active backing of Ukraine has astonished many worldwide analysts, notwithstanding the fact that the hard-right *Fratelli d'Italia* party had collaborated with Russia previously. Since February 2022, Rome has been one of the primary sources of weapons to Ukraine, delivering numerous howitzers, IFVs, and other military equipment.[572] Italy's foreign policy rests on its robust membership within NATO and the European Union, as well as a close alliance with the United States. An additional significant difficulty for Italy is the escalating unpredictability of its southern border, which involves irregular migrations and an augmenting competition for security in the Mediterranean region.[573] Italy aims to enhance its ability to tackle upcoming threats at both national and supranational levels by collaborating with NATO and the EU. To endorse an ambitious defence and security strategy that aligns with contemporary times, the Meloni administration has unveiled a "three-year investment law" to raise and preserve military expenditure in the medium term.[574]

Based on SIPRI's Defence Expenditure Database, Italy is the fourth country spending the most on defence in Europe.[575] Yet, Italy's investment in military-related R&D is comprised between 50 and 2'000 million a year according to accessible sources, making it difficult to comment further. In Italy *"(…) the situation of innovation policy in the defence sector is rather peculiar, mixed and static."*[576] The defence-innovation budget is managed by the National Plan on Military Research (Piano Nazionale di Ricerca Militare, PNRM), monitored both by the MoD and the Ministry of Economic Development. This investment in R&D represent the PNRM, but other funds from the 2 billion procurement fund of the MoD might also go in defence-related R&D, which makes it difficult to articulate a definitive figure concerning state R&D investment on defence-related projects. Most of Italy's innovation occurs through multiannual procurement programmes with considerable administrative constraints. This explains Italy's lag behind the UK, France, and Germany in terms of defence-related innovation. Italy's institutional shape, specifically its large and complex bureaucracy, regularly changing government, and numerous overlaps between ministries' prerogatives, impedes its innovation capacity. Moreover, the configuration of Italy's defence sector, characterised by a small

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[570] Andornino, Giovanni B. et al., "La Cina: sviluppi interni, proiezione esterna", Osservatorio di Politica Internazionale*, Torino World Affairs Institute*., September 2020.: 57.
[571] Roberts, Hannah. Italy and Russia: A love affair that hasn't quite ended, *Politico*, https://www.politico.eu/article/italy-russia-love-affair-no-end/, 6 April 2022. (Accessed on 20.09.2022)
[572] Mitzer, Stijn and Oliemans, Joost. Guns Not Gnocchi: Italian Military Aid To Ukraine, *Oryx*, https://www.oryxspioenkop.com/2023/05/guns-not-gnocchi-italian-military-aid.html, 22 May 2023. (Accessed on 29.06.2023)
[573] Italy, Mediterranean Security and European Defence, Events Paper, *Friends of Europe*, https://www.friendsofeurope.org/wp/wp-content/uploads/2019/04/06-25-SEC-PUB-Italy-study-launch-Brussels.pdf, 2019. (Accessed on 20.10.2022)
[574] To face the Russian threat, Europeans need to spend together – not side by side, *Euractiv*, https://www.euractiv.com/section/defence-and-security/opinion/to-face-the-russian-threat-europeans-need-to-spend-together-not-side-by-side/, 19 April 2022. (Accessed on 04.07.2023)
[575] World military expenditure passes $2 trillion for first time, *Stockholm International Peace Research Institute (SIPRI)*, https://www.sipri.org/media/press-release/2022/world-military-expenditure-passes-2-trillion-first-time, 25 April 2022. (Accessed on 21.09.2022)
[576] Marrone, Alessandro and Gilli, Andrea. "Defence Innovation: New Models and Procurement Implications. The Italian Case", *Armament Industry European Research Group (ARES)*, 2020.: 3.

number of key players (Leonardo-Finmeccanica, Fincantieri, Iveco, etc.) and numerous SMEs that typically serve as subcontractors for bigger firms, poses challenges to the implementation of "grassroots" innovation from the bottom up.[577] Rome has progressively sought to adapt its innovation ecosystem, notably by adopting top-down policies able to reform it. The establishment of the Centre of National Innovation (Ufficio generale innovazione della difesa, UGID) brings it closer to a coherent institution monitoring nationwide defence-related innovation, an old project supported by Italian defence experts encouraging the establishment of an “Italian DARPA”.[578] But there remains a lot of work to do before Italy can smoothen its processes of developing, procuring, and fielding innovative combat systems.

The Italian defence establishment has long identified innovation as a core component of national security, as it appears in many official documents. In the *Chief of Defence’s Strategic Concept of 2020*, it is stated that Italy will *“(…) move towards a more strategic, structured long-term approach aiming at prioritizing technological areas and allocating investments in a more efficient and effective way.”*[579] Robotics and autonomous systems are recognised as potentially revolutionary developments for the defence industry. Italy has been at the forefront of driving innovation in this area, particularly through the new *Strategic Compass* of the EU, which seeks to foster greater collaboration among members on defence research and development.[580] As mentioned earlier, the main weakness of Italy’s defence-related innovation system is the fact that it is underfunded by the government.

However, the economy of Italy as a whole possesses certain comparative advantages. First, Italy possesses a very good research ecosystem, composed of world-class universities and independent research institutes (including 4 ATITCs) allowing it to *“(…) punch above its weight in comparison to other countries.”*[581] A key establishment in this field is the Italian Institute of Technology (Istituto Italiano di Tecnologia, IIT). It carries out cutting-edge research on various technologies, including autonomous systems, robotics, and AI.[582] Secondly, due to the nature of the Italian defence economy, small and medium-sized enterprises have formed networks, making them stronger and more resistant together. Certain SMEs are highly specialised, possessing niches in which they possess exceptional expertise.[583] However, there is a need for a systematic integration of academia, government-supported institutions, and private sector stakeholders to develop a robust and fruitful defence-related innovation system that can effectively provide for the needs of the armed forces.[584] In other words, Italy needs organisational reforms that allow its government to make the most of the great potential of its existing minds and defence industry actors.

Although a reform of the country’s political institutions could be beneficial, most governments cannot achieve significant change due to weak, short-lived coalitions. Despite this, there is a drive to transform the defence innovation domain into a more effective apparatus, as recent

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577 Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 186.
578 Kington, Tom. New bill could get Italy its own DARPA, *Defense News,* https://www.defensenews.com/smr/cultural-clash/2020/01/29/new-bill-could-get-italy-its-own-darpa/, 29 January 2020. (Accessed on 19.09.2022)
579 Generale Vecciarelli, “Il Concetto Strategico del Capo di Stato Maggiore della Difesa (SMD)”, *Ministero Della Difesa*, 2020.: 6.
580 Calcagno, Elio et al., “La Bussola strategica UE e dodici sfide per l’Italia”, *Istituto Affari Internazionali (IAI)*, Issue 22, 2022.: 8.
581 Marrone, Alessandro and Gilli, Andrea. “Defence Innovation: New Models and Procurement Implications. The Italian Case”, *Armament Industry European Research Group (ARES)*, 2020.: 9.
582 Interview at the Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia (IIT), 23 March 2023.
583 *Ibid.*
584 Ammiraglio Cavo Dragone, “Il Concetto Strategico del Capo di Stato Maggiore della Difesa (SMD)”, *Ministero Della Difesa*, 2022.: 22.

developments have shown. The first line of effort is to increase the government's expenditure on defence innovation. This process was initiated by Minister of Defence Guerini in October 2019 in front of a Joint Chambre of Deputies-Senate Defence Committee to request additional funding for the Centre of Defence Innovation (Centro Innovazione della Difesa, CID).[585] According to Colonel Paolo Sandri, head of the CID, *“In a faster-paced world where technology has a rapid obsolescence, the idea is to adopt agile management: if there is something innovative, we insert it at prototype level and learn from mistakes, before making a final choice.”*[586] The second line of effort concentrates on making the UGID more suitable to spark civilian technologies as well as stimulate and coordinate their development to spin-off in military applications.[587] In 2022 a bill was introduced at the parliament to reinforce UGID’s mandate by providing it with a testing facility and the ambition of transforming it into the “Italian DARPA”. This move is supported by the military establishment and most political parties.

One constraint of Italy is its capacity to undertake top-notch research through sponsored partnerships, but it struggles to generate spin-offs capable of attracting investors to fabricate end products.[588] Parallelly, the aim is also to establish a multiannual plan for the Defence Technological Industrial Base (DTIB), giving continuity to the public policy in this domain.[589] Finally, the centrality of European cooperation for Italy in defence-related innovation must be highlighted: *“The Italian military, as well as major players like Leonardo and Fincantieri, increasingly see PeSCo and the EDF as incubators of robust procurement or research and development (R&D) projects related to capabilities which are considered crucial for the Italian armed forces and DTIB.”*[590] Yet, Italy’s defence industry’s strong ties with America’s, with champions Leonardo and Fincantieri partly owned by US groups create *de facto* limitations to the degree of Rome’s involvement in European defence-related projects.[591] To evaluate Italy's alignment with the remaining innovation drivers, one should take into account that (2) defence recognises innovation as a crucial aspect, (3) innovation governance is progressively being reformed, with much room for improvement, and (4) the level of collaboration between private sector, academia, and government is dissatisfactory.

Short of a formal military doctrine detailing the use of military robotics or even an AI strategy, the Italian armed forces are considerably proficient in incorporating autonomous systems into the armed forces, both intellectually and practically.[592] The goal is to develop systems able to complement, augment and team-up with the human operator. A document released by the MoD on the Impact of EDTs on Defence (*L’impatto delle Emerging Disruptive Technologies sulla Difesa*), distinctly mentions that *“The objective is to make sustainable and efficient the*

[585] Minister Guerini: New Guidelines Illustrated to the Defence Committee, *Ministry of Defence*, https://www.difesa.it/EN/Primo_Piano/Pagine/minister_guerini_new_guidelines_illustrated_to_the_defence_committee.aspx, 30 October 2019. (Accessed on 21.09.2022)
[586] Zorloni, Luca. Quali sono le nuove tecnologie che l'esercito italiano vuole mettere alla prova, *Wired*, https://www.wired.it/attualita/tech/2021/03/17/esercito-italia-tecnologie-droni-robot-intelligenza-artificiale/, 17 March 2021. (Accessed on 20.09.2022)
[587] Kington, Tom. New bill could get Italy its own DARPA, *Defense News,* https://www.defensenews.com/smr/cultural-clash/2020/01/29/new-bill-could-get-italy-its-own-darpa/, 29 January 2020. (Accessed on 19.09.2022)
[588] Interview at the Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia (IIT), 23 March 2023.
[589] Marrone, Alessandro and Gilli, Andrea. “Defence Innovation: New Models and Procurement Implications. The Italian Case”, *Armament Industry European Research Group (ARES)*, 2020.: 6.
[590] *Ibid.:* 8.
[591] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 180.
[592] Gilli, Andrea and al. “Exploring the Benefits of a New Force Enabler – Defense AI in Italy”, *Defense AI Observatory*, May 2022.: 17.

military operations under the paradigm of Manned-Unmanned Teaming (MUMT).”[593] The document highlights the potential of military robotics to transform the battlefield, alter tactics, and reshape command structures. At the tactical level, military robotics are considered ideal for ISR tasks, logistical support, and defensive operations due to their resiliency and perseverance. As Colonel Sandri declares: *“We work on technologies enabling personal protection, mobility and situational awareness.”*[594] Rome is closely observing lessons being learned by its traditional partners: *“Italy is planning to create a network that connects all the national actors involved in the development of AI and other technologies considered to be of ‘strategic value’.”*[595] Figure 24 details Italy’s markets for each type of unmanned system.

Relatively to the three previous countries, Italy’s markets in UAVs, UGVs, and UMSs are smaller. Overall, the military robotics market is projected to grow by 16.81% between 2020 and 2025, slower than the UK, France, and Germany. In 2019, the UAV market represented USD 103.1 million, and it is expected to grow to 253.1 million by 2025. The Italian military has been using the MQ-9 Reaper and RQ-11 Raven since 2009 and its purchase of two of the earlier from the US for USD 63 million.[596] As Table 7 in Appendix shows, Italy additionally operates systems from different countries, including Bramor from Slovenia, Camcopter S-100 from Austria, MQ-9 Reaper, MQ-1 Predator and RQ-7 Shadow from the US as well as five indigenously produced models. A good illustration of Italy’s homemade UAV production is the Falco, a state-of-the-art MALE manufactured by the hardware company Selex Galileo, currently in use by the Italian and Pakistani armed forces.[597] The Falco was first produced in 2009 and has been in use by the Italian army since 2010. Another Italian success story is the SKY X UAV, fielded in 2005 by Alenia Aeronautica and which was the first European UAV to fly in the more than 1’000 kg category.[598] This system was a breakthrough for the Italian industry as it was the first non-American UAV to complete air-to-air refuelling operations successfully, even in adverse conditions.

Platforms	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	103	116	132	152	189	217	253	16.8%
UGVs	10	13	19	28	42	58	80	45%
UMSs	-	2.4	4	6	10	15	21	54.7%
Total	**113**	**131**	**155**	**186**	**241**	**290**	**354**	**22%**

Figure 24 - Italy military robotic and autonomous systems market, USD million. [599]

[593] Ammiraglio Cavo Dragone, “L’Impatto Delle EDTs sulla Difesa, Stato Maggiore della Difesa (SMD)”, *Ministero Della Difesa,* 2022.: 37.
[594] Zorloni, Luca. Quali sono le nuove tecnologie che l'esercito italiano vuole mettere alla prova, *Wired*, https://www.wired.it/attualita/tech/2021/03/17/esercito-italia-tecnologie-droni-robot-intelligenza-artificiale/, 17 March 2021. (Accessed on 20.09.2022)
[595] Gilli, Andrea and al. “Exploring the Benefits of a New Force Enabler – Defense AI in Italy”, *Defense AI Observatory*, May 2022.: 24.
[596] Italy – MQ-9 Reaper Unmanned Aerial Vehicles, *Defense Security Cooperation Agency,* https://www.dsca.mil/press-media/major-arms-sales/italy-mq-9-unmanned-aerial-vehicles, 19 November 2009. (Accessed on 03.10.2022)
[597] Falco Tactical Unmanned Aerial Vehicle (UAV), *Airforce Technology,* https://www.airforce-technology.com/projects/falco-uav/, August 2009. (Accessed on 03.20.2022)
[598] Sky-X Unmanned Combat Aerial Vehicle (UCAV), *Airforce Technology,* https://www.airforce-technology.com/projects/sky-xunmannedaerialv/, 26 May 2010. (Accessed on 04.10.2022)
[599] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 175.

The Italian UGV market accounted for USD 9.9 million in 2019, and it is forecasted to grow by an average of 44.95% each year between 2020 and 2025. Among Italy's purchases figured Milrem's UGV THeMIS enhanced with the Intelligent Functions Integration Kit (MIFIK) to conduct autonomous functions such as waypoint navigation and operations following.[600] Italy expects to develop joint European UGV programs under EDA and PESCO as part of its efforts in this domain. Importantly, the Italian Army has used UGVs to support civilian authorities in times of crisis, for example during the Mirandola earthquake in 2012.[601] On this occasion, the military dispatched teams comprised of both humans and robots to alleviate potential dangers faced by rescuers, yielding favourable outcomes. Thus, Italy has demonstrated that military robotics can be beneficial beyond the scope of military operations, thereby paving the way for increased investment and support in this field. In the field of UMSs, Italy's market is expected to grow to USD 20.9 million by 2025, comparable to the size of France's market. It is the area which is anticipated to witness the most important growth during the 2020-25 period, by an average of 54.64% per year. The Italian company SuperTermoli is currently designing the high-speed and heavily armoured USV ST50 for both the Italian and Greek navies.[602] In addition, Italy is collaboratively developing the PERMEARE, a Small Waterplane Area Twin Hulls (SWATH) type USV, able to recover and launch autonomous vehicles of different natures (gliders, small wire-guided UUVs, etc.)[603]

[600] Ball, Mike. Autonomous UGV Demonstrated to Italian Army, *Defense Advancement,* https://www.defenseadvancement.com/news/autonomous-ugv-demonstrated-to-italian-army/, 6 November 2020. (Accessed on 04.10.2022)
[601] Kruijff, Geert-Jan M., al. "Rescue Robots at Earthquake-Hit Mirandola, Italy: A Field Report." In *2012 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR)*, 1–8. College Station, TX, USA: IEEE, 2012.: 4.
[602] Armed USV (Unmanned Surface Vehicle) built in Greece, *Supertermoli Powerboats* https://supertermoli.com/f/armed-usv-unmanned-surface-vessel-built-in-greece, 2 February 2022. (Accessed on 03.10.2022)
[603] USV PERMEARE, *European Commission*, https://trimis.ec.europa.eu/project/usv-permare, 2015. (Accessed on 04.10.2022)

Spain

Spain is a major player in defence-related R&D, with a government investment of EURO 128.1 million in 2020. However, Spain, like Italy, faces significant challenges due to complex administrative processes and overlapping institutions and ministries that hinder its innovation capacity. Both the Ministry of Defence and the Ministry of Industry, Trade and Tourism are involved in managing R&D projects for the military.[604] It is therefore possible that Spain spends more than what Figure 17 suggests, based on EDA's dataset. According to data from the European Commission, Spain has the vastest innovation ecosystem in Europe with 34 ATITCs, more than France and Germany combined. Yet, most of these centres are predominantly academic and civilian institutions, with only one or a few projects related to military robotics. In Spain, the Directorate General of Armament and Material (DGAM) is responsible for defence R&D and procurement. While the DGAM plays a crucial role, it is not comparable to the French DGA. Spain has not been successful in establishing a similar all-encompassing and centralised agency.[605] Another central institution is the National Institute of Aerospatiale Technics (Instituto Nacional de Técnica Aerospacial, INTA) which regroups the main laboratories of defence and conducts R&D.

Madrid perceives its geopolitical situation through three main elements: (1) stable ties with the US, NATO and EU partners both politically and economically, to secure its Atlantic flank, (2) worries about the increasing competition underway in the Mediterranean space, be it Russia's growing military presence, China's commercial expansionism or Turkey's revisionist designs[606] and, (3) the chronic instability of North Africa and the migration crisis that has hit Spain for a decade.[607] For all these reasons, Madrid plans on sustaining a high level of investment in R&D and fielding of military capabilities.

Spain has acknowledged the importance of innovation in its security policy for a considerable time. However, while the figures for spending on defence-related innovation may appear high, the allocation of resources is relatively low in comparison to the most advanced European nations. Indeed, *"The scarceness of available funds has made innovation in Spain mainly incremental rather than disruptive, based more on exploiting than exploring new technological solutions."*[608] This situation has been caused by four factors. Firstly, there is a clear division between the scientific community and military matters in Spain, primarily due to the population's rejection of the armed forces after more than 35 years of Francoism and military control. Secondly, there is limited investment in research and development for the country's defence sector. In comparison to the OECD's average of 2.7% of GDP spent on R&D, Spain only allocates 1.4% of its GDP to such efforts.[609] Thirdly, the financial support system is fragmented and favours large defence consortiums over start-ups and SMEs, due to the central role of the DGAM. Furthermore, policies regarding defence-related issues are primarily focused on sustaining a national supply chain, which limits the diversification of the defence ecosystem, ultimately inhibiting overall innovation outcomes.[610]

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[604] Defence Technology and Innovation Strategy (ETID) - 2020, *Spanish Ministry of Defence*, 2020.: 46.
[605] Sempere, Carlos. "Defence Innovation: New Models and Procurement Implications. The Spanish Case", *Armament Industry European Research Group (ARES)*, 2020.: 6.
[606] National Security Strategy, *Government of Spain*, 2017.: 43.
[607] Lusenti, Arthur et al. "Conceptions of Peace and Security in Contemporary Europe Probing possibilities for peacebuilding in 2020 and beyond", *Geneva Peacebuilding Platform*, 2020.: 21.
[608] *Ibid.*
[609] Gross domestic spending on R&D: 2022, *OECD*, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.html. (Accessed on 03.10.2022)
[610] Sempere, Carlos. "Defence Innovation: New Models and Procurement Implications. The Spanish Case", *Armament Industry European Research Group (ARES)*, 2020.: 9.

There are still too many barriers for newcomers in the field of defence in Spain, which reduces the capacity of new actors to offer innovative solutions: *"(…) investment in research, technology and innovation is rather low, and there is no master plan to increase synergies with civil actors, as recommended by the European Commission. Thus, the civilian sector remains disconnected from the DTIB."*[611] The archetypal example of this phenomenon is the FCAS project, led by defence industry giants Indra, IPT, Sener and Tecnobit, with minimal participation from small and medium-sized enterprises.[612] Reforms have been conducted but they have not emphasised enough on the necessity to produce a more open defence industrial basis, benefitting from civilian breakthroughs. Spain suffers from a relatively low defence budget and from the fact that its defence firms are not able to compete with other European firms in the market. This is mainly due to the fact that *"The Spanish industry, even having advantage in certain market niches, cannot easily compete with the large conglomerates of countries such as France or Germany and does not have labour costs as low as some European countries."*[613] A clear objective for Spanish authorities is to include Spain's 34 ATITCs more comprehensively and effectively. With regards to other factors that drive innovation, we propose that: (1) Spain has recognised the significance of innovation in defence; (2) existing innovation frameworks require further reformation; and (3) the defence industry is not overly flexible and is unable to benefit from civilian spill-overs due to insufficient permeability for new entrants.

Indeed "The scarceness of available funds has made innovation in Spain mainly incremental rather than disruptive, based more on exploiting than exploring new technological solutions."

In 2020, the Spanish MoD published the *Defence Technology and Innovation Strategy* which explicitly emphasises the importance of UAVs, UGVs, and UMSs.[614] This document highlights the requirement for the Spanish armed forces to gradually integrate unmanned systems and robots, but it does not give further details on the way to do so. The MoD released an updated military doctrine in July 2019, titled: *PDC-01 (A): Doctrine for the employment of the Armed Forces* that indicates broad orientations.[615] Robotics is mentioned only once, with the observation that it will have a significant impact on the conduct of future conflicts.[616] Other publications released by the Ministry of Defence or the armed forces offer further understanding into the potential utilisation of military robotics within the Spanish armed forces. The *National AI Strategy* mentions that combatant systems will not be fully automated with AI.[617] In a website post, the MoD detailed the use of autonomous and robotic systems: logistical support (supply, warehouse management, evacuation of wounded soldiers), ISR, C2 (big data analysis, AI-powered support for decision-making) and protection (exoskeletons for soldiers).[618]

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611 Artéaga, Felix. "Spain". In: Mölling, Christian et al. "European Defense in A New Age (#EDINA) – Geostrategic Changes and European Responses Shaping the Defense Ecosystem", *Deutsche Gesellschaft für Auswärtige Politik (DGAP),* 2023.: 60.
612 Pons, Juan. "Futuro Caza Europea : El Sistama de Armas Siguiente Generaciòn inicia un nuevo periplo hasta 2027", *Revista Espanola de Defensa*, 2021.
613 Hartley, Keith, and Belin, Jean*. The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 229.
614 Technology and Innovation Strategy (ETID) - 2020, *Spanish Ministry of Defence*, 2020: 75; 82; 127-129.
615 Doctrine for the Employment of the Armed Forces, PDC-01 (A), *Spanish Ministry of Defence*, 2019.
616 *Ibid.:* 19
617 Estrategia nacional de Inteligencia Artificial, *Gobierno de Espana*, 2021.
618 Autonomous and Robotic Systems (RAS), *Spanish Ministry of Defence*, https://ejercito.defensa.gob.es/en/reportajes/2019/77_autonomos_roboticos.html, 19 March 2019. (Accessed on 05.10.2022)

The most important market for Spain is for UAVs, accounting for USD 190 million in 2022 and expected to grow to 316 million by 2025. As presented in Table 7, Spain has been purchasing several types of UAVs for two decades, the nEUROn, as well as the RQ-11 Raven, the RQ-20 Puma AE II, the ScanEagle, the RQ-12A Wasp Block IV from the US.[619] Spain further operates Israelian (Orbiter 3, Searcher), Swedish (Skeldar), Norwegian (Black Hornet), Danish (Huginn) and indigenous types of drones (Alcotan, Alpha 800, Condor, SIVA, Atlantic, SUVA, Fulmar X, etc.) In early 2023, Spain has signed a EUR 500 million contract with Airbus for the SIRTAP tactical UAV, which will replace the Searcher.[620]

For UGVs, the market in Spain is comparatively less mature and less developed than the market leaders in Europe, such as the United Kingdom and France. Spain's UGV market is projected to grow from USD 27 million in 2022 to 69 million by 2025. In 2022, Madrid received its inaugural consignment of THeMIS from Milrem Robotics, indicating a proclivity towards further investment in this particular area.[621] Reportedly, the Spanish MoD is about to decide on whether it will purchase Rheinmetall's Mission Master UGVs after a test was conducted successfully between the German firm and the Spanish company Escribano Mechanical & Engineering (EM&E).[622] The Spanish company Sascorp is also in the process of producing the Tellus UGV, an amphibious vehicle expected to be purchased by the Spanish armed forces.[623] In the maritime domain, Spain has fallen substantially behind the most advanced European countries. In July 2022, the Spanish Navy integrated a USV into its fleet for the first time with the test of the USV Vendaval. This small multipurpose patrol boat marks a significant advancement.[624] Yet, Spain is still eyeing R&D in UMS, as the market is expected to expand to reach USD 40 million by 2025.

Platforms	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	190	236	270	316	18.5%
UGVs	27	39	52	69	37.5%
UMSs	15	21	29	40	38.5%
Total	**232**	**296**	**351**	**425**	**22.4%**

Figure 25 – Spain military robotic and autonomous systems market, USD million.[625]

[619] *Ibid*.: 157.
[620] Sirtap, el dron de Airbus en el que España invertirá 500 millones de euros, *Info Defensa*, https://www.infodefensa.com/texto-diario/mostrar/4258831/sirtap-dron-airbus-espana-invertira-500-millones-euros, 20 April 2023. (Accessed on 24.04.2023)
[621] Saballa, Joe. Spain Receives First THeMIS Unmanned Ground Vehicle, *The Defense Post,* https://www.thedefensepost.com/2022/08/11/spain-themis-unmanned-vehicle/, 11 August 2022. (Accessed on 06.10.2022)
[622] Mission Master SP A-UGV Demonstrated in Spain., *Joint Forces,* https://www.joint-forces.com/defence-equipment-news/45672-mission-master-sp-a-ugv-demonstrated-in-spain, 10 August 2021. (Accessed on 07.10.2022)
[623] Spanish Sascorp to Unveil Amphibious UGV at FEINDEF 2021, *Global Defense*, https://www.globaldefensecorp.com/2021/06/14/spanish-sascorp-to-unveil-amphibious-ugv-at-feindef-2021/, 14 June 2021. (Accessed on 06.02.2023)
[624] Navantia Integrates Unmanned Vehicles On Spanish Navy Vessel, *Naval News,* https://www.navalnews.com/naval-news/2022/07/navantia-integrates-unmanned-vehicles-on-spanish-navy-vessel/, 15 July 2022. (Accessed on 07.10.2022)
[625] Figure made by the authors. *Sources*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 177.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The

The Netherlands

Despite its modest proportions and population, the Netherlands invested EUR 87.9 million in defence R&D during 2020, positioning itself as a significant player in Europe. The country is home to five ATITCs, all focused on robotics and human-machine interaction. The Dutch defence innovation *ecosystem "(…) is characterised by a rather open market and by* [many] *SMEs."*[626] The two ministries in charge of defence-related innovation programmes, procurement and planification policies are the Ministry of Defence (MoD) and the Ministry of Economic Affairs (MEA). The Netherlands lacks a centralised institution responsible for overseeing all aspects of defence innovation, unlike France which has AID. Instead, it collaborates with three primary organisations: the National Aviation and Aerospace Laboratory (Nederlands Lucht- en Ruimtevaartcentrum, NLR), the Netherlands Association for Applied Scientific Research (Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk, TNO) and the Maritime Research Institute Netherland (Maritiem Research Instituut Nederland, MARIN).[627] Overall, the Dutch defence architecture retains its decentralised nature and relies on a network-centric approach that is effective to pursue projects, but less so to align the armed forces needs with the country's strategic requirements.[628]

In terms of the country's assessment of its strategic environment, the Netherlands acknowledges three main components that impact its national security as the primary driving factors of innovation in the military domain. The decline of US unipolarity has resulted in the emergence of revisionist powers, including China, Russia and Iran. Additionally, transatlantic differences have underscored the need for Europeans to boost their strategic independence. Meanwhile, political instability within the EU – driven by Brexit, the rise of far-right parties and irregular migration – has been compounded by escalating military tensions in the Mediterranean basin. These factors are prompting the Netherlands to solidify its defence capabilities and increase collaboration with European and transatlantic partners.

The Netherlands has a long tradition of innovation in the field of technology. The Dutch were, after all, the ones who invented corporate governance with the United East India Company, the thermostat, and the modern compass.[629] Interestingly, the present-day Dutch ecosystem is characterised by a significant predominance of bottom-up innovation originating from SMEs with weak ties to the government. Hence, the Dutch defence industry *"(…) consists of 350 large and small companies with a joint turnover of €4.5 billion. The sector employs 25,000 people, (…) almost 8,000 in research and development. The sector is responsible for approximately 0.7% of GDP."*[630] The government's policy on defence-related R&D has been coined "open innovation", and it consists of the efficient partnership between knowledge institutes (the Netherlands has 5 ATITCs), industrial firms with dual-use projects, research labs and state funding.[631] Therefore, the Netherlands has recognised the significance of civilian incubators and accelerators in contributing to the defence innovation ecosystem.

Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews. For Spain, Poland, the Netherlands, Norway, Sweden, Estonia and Switzerland, figures will only be available from 2022.

[626] Sezal, Mustafa Ali, and Giumelli, Francesco. "Technology transfer and defence sector dynamics: the case of the Netherlands." *European Security*, 2022.: 2.

[627] *Ibid*.: 8.

[628] Venema, Auke and van Broekhoven, Pieter. "Keeping the proven old, embracing the new", *European Defence Matters,* Issue 22, 2021.: 21.

[629] McNeil, Ian, ed. *An Encyclopaedia of the History of Technology*. London; New York: Routledge, 1990.: 304.

[630] Defence Industry Strategy, *Netherlands Ministry of Defence and the Netherlands Ministry of Economic Affairs and Climate Policy*, 2018: 11.

[631] *Ibid.:* 25.

However, *"(…) the occurrence of spin-offs is minuscule in the Netherlands."*[632] Consequently, in the Netherlands, *"(…) companies opt to develop their technologies and later adapt these to military needs if the demand arises."*[633]

As the Netherlands' ability to innovate in the military sector depends primarily on SMEs that create technology for civilian markets, institutions like TNO, NLR, and MARIN are responsible for providing an appropriate framework for R&D.[634] This aim is detailed in the *2018 Defence Industry Strategy.* The emphasis on dual-use clarifies the relatively modest size of the Dutch defence sector, which generated a turnover of EURO 4.54 billion in 2014, given that a majority of its pursuits are not exclusively defence-oriented.[635] According to the Dutch MoD's *Defence Strategic Knowledge & Innovation Agenda 2020*: *"(…) the Netherlands will continue to both invest in classical (long-term) defence R&T and, simultaneously, increase their efforts to apply available civil technology for military purposes, in what is called 'short cyclical innovation'."*[636] Nevertheless, it is worth mentioning that despite this comparatively small revenue, the Dutch defence industry is internationally recognised for being a dependable supplier of components and sub-systems, as well as of top-of-the-range equipment such as ballistic missiles, submarines, and frigates (Damen Schelde Naval shipbuilding is a prominent global leader in the field of maritime armaments).[637]

> *The current Dutch ecosystem is still marked by this strong predominance of bottom-up innovation, emerging from SMEs with loose links to the state.*

The Dutch authorities aim to integrate the country's defence industry into European, transatlantic and, where possible, international supply chains. The objective is to safeguard market niches and ensure a stable flow of supplies. The Netherlands is involved in various innovation and technology development projects initiated by the EU and NATO, with a particular focus on those led by EDA. However, as a prominent player in multiple emerging digital technologies, such as AI and robotics, the country has relatively lower motivation than its peers to utilise these tools for project progression.[638] Concerning the additional factors that stimulate innovation, the Netherlands possess (1) a robust innovation culture based on an accessible and dispersed system, (2) enjoy the benefits of a dynamic defence industry despite the limited size of the domestic market, as well as an efficient research and development ecosystem, and (3) are adapting to a future of nationalisation or regionalisation of the defence supply chain in which they will have to enhance their export-oriented strategy to obtain more opportunities for civilian spillovers.

Military robotics and autonomous systems are identified by the Dutch authorities as important components of the country's overall military doctrine. The last *Defence Strategy* points out that *"Robots and autonomous systems can make the armed forces more efficient and safer. They offer abilities for mapping out new environments quickly and safely, without endangering*

[632] Sezal, Mustafa Ali, and Giumelli, Francesco "Technology transfer and defence sector dynamics: the case of the Netherlands." *European Security,* 2022.: 11.
[633] *Ibid.*
[634] *Ibid.:* 29
[635] De France, Olivier et al., "Defence Industrial Policy in Belgium and the Netherlands", *Armament Industry European Research Group (ARES)*, 2016.: 10.
[636] Venema, Auke and van Broekhoven, Pieter. "Keeping the proven old, embracing the new", *European Defence Matters,* Issue 22, 2021.: 20.
[637] Sik, Ko Swan. "The Dutch-Taiwanese Submarines Deal: Legal Aspects." *Netherlands Yearbook of International Law* 13, December 1982.: 125.
[638] Interview with the Royal Netherlands Army, 13 Light Brigade's Robotic and Autonomous Systems (RAS) Unit, 19 June 2023.

military personnel. As such, these systems can offer important operational and logistic advantages."[639] Furthermore, the *2019 Netherlands Defence Doctrine* considers that new technologies such as unmanned systems are significant, but not revolutionary. As it is stated, *"Despite advances in unmanned technology and developments in robotics, the human factor remains key."*[640] In fact, the Royal Netherlands Army has developed a handbook detailing the use of UGVs in many contexts, based on the Concept Development and Experimentation (CD&E) done by the RAS Unit.[641] The Dutch armed forces intend to use military robotics mainly for ISR, support missions and logistical tasks. Indeed, the Dutch armed forces will explore *"(…) possibilities for computerised and unmanned systems to take over tasks currently performed by people."*[642]

Generally speaking, the aim is to incorporate robotic systems into existing doctrine without creating a new one. The *Defence Vision 2035* states clearly that *"There are simply some things we will never be able to leave to robots, such as decisions about life and death."*, indicating that fully autonomous lethal systems will not be used by the Dutch armed forces in the foreseeable future.[643] Although the Netherlands is reportedly developing a military AI strategy, it is unclear whether such a document will specify the use of military robotics and autonomous systems within the armed forces.[644] A report released by the think tank HCSS highlights that the Dutch armed forces have made advances in their doctrinal thinking about how to use and integrate military robotics: *"RAS are unique in that they ultimately can take humans 'out of the loop' and as a consequence, drastically affect operational performance, organizational embedding (…), and operational concepts (doctrines and tactics)."*[645]

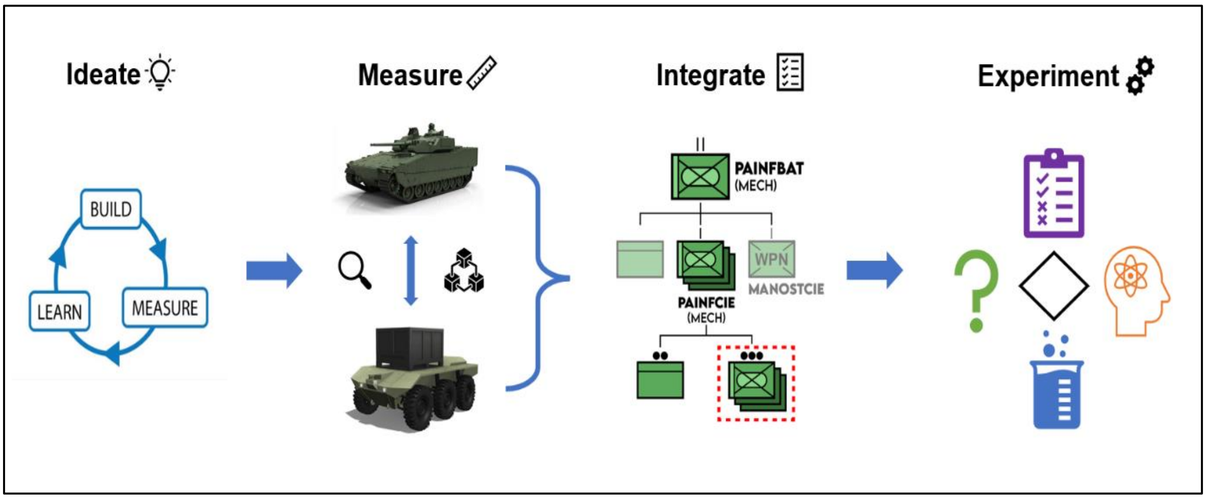

Figure 26 - RAS Unit's "Roadmap of Innovation Process".[646]

[639] Defence Industry Strategy, *Ministry of Defence and Ministry of Economic Affairs and Climate Policy*, 2018.: 45.
[640] Netherlands Defence Doctrine, *Ministry of Defence*, 2019.: 69.
[641] Interview with the Royal Netherlands Army, 13 Light Brigade's Robotic and Autonomous Systems (RAS) Unit, 19 June 2023.
[642] *Ibid.*
[643] Defence Vision 2035 – Fighting for a Safer Future, *Ministry of Defence*, 2020.: 26.
[644] Gray, Maggie and Ertan, Amy. "Artificial Intelligence and Autonomy in the Military: An Overview of NATO Member States' Strategies and Deployment: Overview document and Appendix A (Country Profiles)", *NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE)*, 2021.: 26-27.
[645] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS)*, 2022.: 16-18.
[646] Figure made by the authors. Interview with the Royal Netherlands Army, 13 Light Brigade's Robotic and Autonomous Systems (RAS) Unit, 19 June 2023.

The Royal Netherlands Army is the first organisation to incorporate a military robotics unit in one of its operational brigade, namely the 13th Infantry Light Brigade.[647] The purpose of this unit is to establish a structure that facilitates the straightforward exchange of information between end-users and innovation producers to identify requirements, conceive ideas and outline research aims.[648] In 2018, the RAS Unit was established with the goal of promoting innovative approaches through experimentation with UGVs. The unit facilitates grassroots innovation and short-cycles development processes, emphasising the need for intensive testing at all stages of the innovation process. The focus is on creating novel solutions that challenge conventional thinking and push boundaries.[649] The RAS Unit combines an entrepreneurial methodology with a military ethos in order to expedite tasks efficiently and definitively, while striving to minimise laborious administrative procedures.

The "Roadmap" (Figure 26 above) depicts the entire process of developing, integrating and using UGVs within the unit. What is crucial is that this process includes Capability Development and Experimentation (CD&E) at each stage, allowing for a comprehensive comprehension of technological advancement and the corresponding enhancements of usage concepts.[650] The RAS Unit's success story can be attributed to its founders' incremental approach. They began by purchasing off-the-shelf UGVs and directly engaging military personnel to evaluate how they interacted with these systems. Thereafter, by determining the military's specifications, this first phase enabled the RAS Unit to progressively collaborate with innovators and the defence industry to produce systems that satisfy these requirements. The experimentation of these systems during exercises established the prerequisites for advancing the development of usage conceptions at the tactical tier (group, platoon, company) and commencing an assessment of their application at battalion and brigade tier.[651] According to the interviewee, this way of working has been highly disruptive within the military institution, helping to implement a new way of working and targeting fast-track innovation as an end in itself.[652]

Platforms	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	135	167	192	224	18.5%
UGVs	19	28	37	49	38%
UMSs	8	11	15	21	37.8%
Total	**162**	**206**	**244**	**294**	**22%**

Figure 27 – The Netherlands military robotic and autonomous systems market, USD million.[653]

[647] 13th Light Brigade, *Royal Netherlands Army*, https://english.defensie.nl/organisation/army/units/13-mechanised-brigade. (Accessed on 09.05.2023)
[648] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS)*, 2022.: 20.
[649] Interview with the Royal Netherlands Army, 13 Light Brigade's Robotic and Autonomous Systems (RAS) Unit, 19 June 2023.
[650] *Ibid.*
[651] *Ibid.*
[652] *Ibid.*
[653] Figure made by the authors. *Sources:* Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A

As for many other countries, the most important market is for UAVs, as shown by Figure 27 above. The Dutch military has used UAVs for a long time and has at least 8 different types in its storage. This includes the RQ-11 Raven and RQ-20 Puma purchased from the US as well as the Black Hornet Nano, a Danish-made micro drone used for reconnaissance by the *Kommandotroepen.*[654] Moreover, the Dutch are currently participating in the development and production of the Scan Eagle UAV and are collaborating with Saab on the Skeldar V-200, a VTOL helicopter for its navy.[655] It is the first time that the Netherlands will produce partly-designed homegrown UAV capabilities (Table 7). The Dutch market for UAVs will increase from USD 135 million in 2022 to 224 million by 2025. Reportedly, the Dutch armed forces will acquire 7 THeMIS UGVs from Milrem Robotics in the upcoming years and an unspecified amount of Mission Masters from Rheinmetall as part of a Concept Development & Experimentation (CD&E) programme.[656]

The UGV market for the Netherlands will reach USD 49 million by 2025, marked by a significant growth. The Royal Netherlands Army focuses on operational wheeled vehicles to improve off-road performance and better protection of its forces. As it is noted in the HCSS report: *"With a horizon of 15 years, the army will invest in experimentation in a wide range of combat UGVs including the further development of the corresponding AI."*[657] In the field of UUVs/USVs, the Netherlands has invested steadily, fielding at least three types of systems: the HUGIN UUV, the Remus UUV and the A-18M UUV. The latter, produced by ECA Group, is used for mine clearing and countermeasure. It was the object of a joint purchase worth EURO 24 million by the Dutch and Belgian navies.[658] The Dutch Royal Navy will also purchase the Seagull, a USV developed by the Israeli manufacturer Elbit, who is specialised in anti-submarine warfare that will furniture the next generation of frigates.[659] The UMS market for the Netherlands will grow from USD 8 million to 21 million in 2025. This development is supported by the fact that the Netherlands is a prominent player in the area of traditional naval capacities, owing to its historical legacy as a maritime power.

Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews.

[654] Black Hornet-onbemand verkenningssysteem, *Ministry of Defence*, https://www.defensie.nl/onderwerpen/materieel/vliegtuigen-en-helikopters/black-hornet-onbemand-verkenningssysteem, 26 October 2018. (Accessed on 07.10.2022)

[655] Hoyle, Craig. Skeldar V-200 selected for Belgian/Dutch navy programme, *Fight Global*, https://www.flightglobal.com/military-uavs/skeldar-v-200-selected-for-belgian/dutch-navy-programme/139197.article, 8 July 2020. (Accessed on 08.10.2022)

[656] Ball, Mike. Rheinmetall Mission Master UGV Trialled by Dutch Army, *Unmanned Systems Technology*, https://www.unmannedsystemstechnology.com/2020/11/rheinmetall-mission-master-ugv-trialled-by-dutch-army/, 15 November 2020. (Accessed on 10.10.2022)

[657] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS)*, 2022.: 20.

[658] Manaranche, Martin. Royal Netherlands Navy Started Evaluation Of Its Future Mine Warfare Toolbox, *Naval News,* https://www.navalnews.com/naval-news/2021/08/royal-netherlands-navy-started-evaluation-of-its-future-mine-warfare-toolbox/. 23 August 2021. (Accessed on 10.10.2022)

[659] Karremann, Jaime. Unmanned anti-submarine warfare, 'we can't escape it', *Navies Worldwide* https://naviesworldwide.com/navy-news/unmanned-anti-submarine-warfare-we-cant-escape-it/. 28 October 2020. (Accessed on 10.10.2022)

Poland

Poland's significance in European and transatlantic security has grown, as indicated by its preparedness to protect NATO's eastern flank during the recent conflict in Ukraine. In 2017, Poland spent EURO 53.2 million on defence-related R&D, or around 0.5% of its overall defence budget.[660] Additionally, Poland has three ATITCs, specialised in robotics and AI. Yet, because of its Soviet legacy and a heavy bureaucracy, *"(…) the vast majority of Polish DTIB remains directly owned by the state."*[661] The Polish government not only owns the majority of defence-related companies, but these firms are primarily focused on the domestic market, with exports only contributing a small portion of their total revenue. To further enhance its control, the Polish state established the Polish Armaments Group (Polska Grupa Zbrojeniowa, PGZ) in 2014, which consolidated all state-owned defence enterprises.[662] The coordination of defence and industrial policy has been impeded by a state-centred approach, which has in turn hindered the country's innovative capacity in the defence sector.

The defence sector in Poland has undergone a series of reforms in recent years, leading to a progressive reversal of its innovation system. In January 2022, the country launched the Armaments Agency (Agencja Uzbrojenia, AU) to centralise and streamline all aspects of procurement processes and armament programs. Additionally, the Innovation Department (Departament Innowacji, DI) has been created within the Ministry of National Defence (MND) to further integrate and streamline dual-use technologies in defence-related R&D. The defence sector in Poland has undergone several reforms in recent years, resulting in a progressive reversal of its innovation system. In January 2022, the Armaments Agency (Agencja Uzbrojenia, AU) was launched to centralise and streamline all aspects of procurement processes and armament programs. Furthermore, the Ministry of National Defence (MND) has established the Innovation Department (Departament Innowacji, DI) to enhance the integration and simplification of dual-use technologies in research and development related to defence.[663], and (3) the increasing importance of regional security partnerships, especially with Romania, the Visegrad Group (V4), the Baltic and Nordic states through the Bucharest Nine format.[664] Russia's aggression towards Ukraine has confirmed Warsaw's assessment, bolstering its determination to pursue its objectives in the realm of defence.

Since 2014, Poland has undertaken a comprehensive effort to rearm and reform its armed forces. This initiative has entailed a significant expansion of military personnel, including the establishment of a Territorial Defence Force (TDF), as well as a transition from outdated Soviet-era equipment to modern Western-style armaments. To this end, the Polish Ministry of National Defence (MND) has proposed the Technical Modernisation Plan (TMP), which seeks to equip the armed forces with cutting-edge systems and capabilities, with a particular emphasis on transitioning from Soviet legacy equipment to Western standards.[665] This

[660] Klincewicz, Krzysztof and Marczewska, Magdalena. "Polish Systems of Innovations – trends, challenges and policies", *University of Warsaw*, 2017.: 10.
[661] Terlikowski, Marcin." Defence and Industrial Policy in Poland – Drivers and Influence", *Armament Industry European Research Group (ARES)*, 2017.: 4.
[662] *Ibid.:* 4-5.
[663] National Security of the Republic of Poland, *Office of the President of the Republic*, 2020.: 7.
[664] Jarocki, Michal. The Priorities of Poland's Foreign and Security Policy, *European Security & Defence*, https://euro-sd.com/2019/09/articles/14444/the-priorities-of-polands-foreign-and-security-policy/, 19 September 2019. (Accessed on 11.10.2022)
[665] Terlikowski, Marcin. "Poland". In: Mölling, Christian et al. "European Defense in A New Age (#EDINA) – Geostrategic Changes and European Responses Shaping the Defense Ecosystem", *Deutsche Gesellschaft für Auswärtige Politik (DGAP),* June 2023.: 51.

program will account for a total investment of EURO 118 billion between 2021 and 2035.[666] Moreover, the Polish government announced in 2017 the *Defence Concept*, which expresses an interest in harnessing EDTs.[667] These recent advancements position Poland among the nations globally that allocate a substantial proportion of their economic output towards defense expenditures, surpassing 2.3% of its GDPin the year 2020.[668] In reaction to the Ukrainian crisis, the Polish government has recently announced that it will augment this figure to 4% in the foreseeable future.[669] However, it should be noted that an increase in budget allocation does not necessarily translate to improved outcomes, as the Polish system continues to be impeded by protracted administrative procedures and limited utilisation of the nation's innovative potential. In fact, until recently, numerous technologies were deemed unattainable by domestic industries themselves, who opted to procure equipment directly from external sources rather than embark on protracted and precarious indigenous development initiatives (such as the F35 fighter jets and MIM-104 Patriot missile defense systems). This outcome is a consequence of Poland's reliance on the USSR for arms procurement over the course of half a century, which resulted in the loss of an innovation ethos that characterised the nation during the Warsaw Pact era.

Moreover, Poland’s DTIB almost entirely collapsed at the end of the Cold War, leaving a sector in complete ruins.[670] Reforms have since been implemented, but the set-up of PGZ as a highly centralised and overarching institution in 2013 has been described by certain defence experts as being a *“(…) a relic of the Soviet era industrial structure and an outlier in the otherwise dynamic and increasingly market-savvy Polish manufacturing industry.”*[671] Poland’s level of investment in R&D relative to the overall defence budget is small, never exceeding 1.4% over the 2010-2020 period. Truly, *“Poland more often seeks offsets and off-the-shelf acquisitions than R&T/D as ways of acquiring new capabilities.”*[672] Polish industrial enterprises have consistently demonstrated a strategic focus on the adaptation of foreign systems to cater to the specific requirements of their armed forces, rather than solely relying on indigenous design and production of military equipment. This phenomenon, commonly referred to as "Polonisation," has yielded favorable outcomes for Warsaw, as evidenced by the successful refurbishment of Finnish APCs, German tanks, and Korean howitzers to conform to contemporary operational standards. However, Poland has also showcased its capability to independently manufacture sophisticated military equipment, exemplified by the Borsuk IFV, which experts regard as one of the most ambitious and efficient systems of its generation.[673]

Poland's involvement in European defense cooperation initiatives is generally perceived as limited. The country's participation is confined to a mere 14 projects, which have been initiated and supported by various EU institutions. Yet, this includes two military robotic projects: the Maritime Semi-Autonomous System for Mine Countermeasures (MAS MCM) and the

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666 Terlikowski, Marcin. “Defence Innovation: New Models and Procurement Implications, the Polish Case”. *Armament Industry European Research Group (ARES)*, March 2022.: 5.

667 Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; The International Institute for Strategic Studies, 2022.: 135.

668 *Ibid.:* 134.

669 Poland to ramp up defense budget to 4% of GDP, *Deutsche Welle*, https://www.dw.com/en/poland-to-ramp-up-defense-budget-to-4-of-gdp/a-64555544, 20 January 2023. (Accessed on 28.06.2023)

670 Terlikowski, Marcin. “Defence Innovation: New Models and Procurement Implications, the Polish Case”. *Armament Industry European Research Group (ARES)*, March 2022.: 6.

671 Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 257.

672 *Ibid.:* 8.

673 Adamowski, Jaroslaw. Poland eyes 1,400 new fighting vehicles to replace Soviet-era rides, *Defense News,* https://www.defensenews.com/global/europe/2023/02/28/poland-eyes-1400-new-fighting-vehicles-to-replace-soviet-era-rides/, 28 February 2023. (Accessed on 18.04.2023)

Integrated Unmanned Ground System (ESSOR).[674] With Poland prioritising NATO over the EU in most defence-related matters, it is logical to expect Warsaw to become more involved in the coming years, especially with the advent of DIANA and the strengthening of other NATO institutions in the field of defence-related R&D.[675] This is especially true in a context of tensions between Brussels and Warsaw over the latter's implementation of the EU's rule of law principle.[676] Regarding the other factors driving innovation: (1) there is an increasing push, even though insufficient, towards innovation in the military domain sustained by the authorities and population at large in Poland; (2) reforms are leading to a more innovation-friendly environment, notably with the establishment of AU, but the system remains too state-centred and not enough inclusive of academia; (3) investment is deemed inadequate and characterised by inefficiency, but it is anticipated that the forthcoming augmentation in the defence budget will rectify this situation.

With Poland prioritising NATO over the EU in all defence-related matters, it is logical to expect Warsaw to become more involved in the coming years, especially with the advent of DIANA and the strengthening of other NATO institutions in the field of defence-related R&D.

Poland recognises the importance of robotics in the military domain, but the country's official documents also point out that conventional forces will, by far, remain the main component of the armed forces.[677] This was substantiated through Poland's considerable defence agreement with South Korea, which was officially ratified in July 2022. This accord encompassed a significant number of tanks, howitzers, and various other military equipment.[678] In a broader context, this agreement serves as an indication that Poland is currently undergoing a transformative phase, positioning itself to emerge as a prominent and influential land force within the European continent in the foreseeable future.[679] The Polish defence establishment considers that *"(…) the Robotic Revolution in Military Affairs brings about a real chance to establish joint European armed forces increasing overall strength and efficiency."*[680] Thus, investing in military robotics is both a way to improve sensitive capabilities and to strengthen collaboration with key security partners. Poland does not have a doctrine on military robotics, autonomous systems, or an AI military strategy. The *Defence Concept of the Republic of Poland* is the armed forces' basis document but it only provides snippets of information regarding military robotics, their uses, integration, and conceptualisation.[681] It considers that in the battlefield of the future, the importance of automated systems will

[674] Zaborowski, Marcin. Poland and European Defence Integration, *European Council on Foreign Relations (ECFR)*, https://ecfr.eu/publication/poland_and_european_defence_integration/, 25 January 2018. (Accessed on 11.10.2022)
[675] Poland in NATO – More than 20 years, *Ministry of National Defence,* https://www.gov.pl/web/national-defence/poland-in-nato-20-years. (Accessed on 07.12.2022)
[676] Europe's week: Poland in spotlight over EU rule of law, *Euronews,* https://www.euronews.com/my-europe/2021/10/22/europe-s-week-poland-in-spotlight-over-eu-rule-of-law, 25 October 2021. (Accessed on 08.12.2022)
[677] The Defence Concept of the Republic of Poland, *Ministry of National Defence*, May 2017.
[678] Lendon, Brad. Poland to buy hundreds of South Korean tanks, howitzers after sending arms to Ukraine, *CNN,* https://edition.cnn.com/2022/07/27/asia/south-korea-poland-tanks-howitzer-ukraine-intl-hnk-ml/index.html, 19 September 2022. (Accessed on 11.10.2022)
[679] Karnitschnig, Matthew and Kosc, Wojciech. Meet Europe's coming military superpower: Poland, *Politico,* https://www-politico-eu.cdn.ampproject.org/c/s/www.politico.eu/article/europe-military-superpower-poland-army/amp/, 21 November 2022. (Accessed on 22.11.2022)
[680] Zajac, Maciej. The Robotic Revolution in Military and Poland's National Security Strategy, *The Warsaw Institute,* https://warsawinstitute.org/robotic-revolution-military-polands-national-security-strategy/#_ftnref1 https://warsawinstitute.org/robotic-revolution-military-polands-national-security-strategy/#_ftnref19 9, 24 September 2018. (Accessed on 12.10.2022)
[681] The Defence Concept of the Republic of Poland, *Ministry of National Defence*, May 2017.: 3.

increase.[682] Interestingly, the document leads us to think that the Polish armed forces will potentially use AI and autonomous systems as enablers of faster decision-making processes: *"By 2032, we will possess autonomous systems enabling commanders to grasp the full operational picture and to take faster decisions."*[683] Other uses pictured for military robotics include ISR, simplified C2 and logistical support.

Platforms	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	115	143	163	191	18.4%
UGVs	17	24	31	42	37%
UMSs	7	10	13	18	38%
Total	**139**	**177**	**207**	**251**	**22.4%**

Figure 28 – Poland military robotic and autonomous systems market, USD million.[684]

Figure 28 highlights the trends of the three different components of Poland's military robotics market between 2022 and 2025. Poland's air force and navy have been using ScanEagle (US), RQ-21 Integrator (US), Orbiter (Israel) for several years. [685] In addition, Warsaw is currently purchasing at least three additional types of UAVs all of them nationally produced: the Orlik PGZ-19R, the FlyEye and the PIT-Radwar.[686] WB electronics is a successful polish firm that produces loitering munitions and small UAVs.[687] Poland's entrance in the UAVs industry is relatively new and is so far restricted to Class I UAVs, namely small, short-range and light systems. Warsaw will remain reliant on foreign sources of procurement for larger UAV systems such as HALE or MALE, notably from the US. The UAV market is expected to increase from USD 115 million in 2022 to 191 million in 2025.

Indigenous models of UGVs are slowly appearing in Poland, mainly as a response to the Russian threat. The best examples of this phenomenon can be found with the Perun UGV and the Robot Lewiatan designed by WB electronics. Both are medium, multi-purpose, and remotely controlled UGVs capable of carrying 7.62mm or 12.7mm machine guns.[688] The Polish UGV market is expected to boom from USD 17 million to 42 million by 2025. In the field

[682] *Ibid*.: 45.
[683] *Ibid*.: 47.
[684] Figure made by the authors. *Sources*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews.
[685] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 156.
[686] Sabak, Juliusz. Polish Ministry of Defence: Four UAV Types to be Delivered Before 2022, *Defence24,* https://defence24.com/armed-forces/air/polish-ministry-of-defence-four-uav-types-to-be-delivered-before-2022*,* 7 February 2022. (Accessed on 12.20.2022)
[687] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 261.
[688] MSPO 2020: Polish-made Perun armed UGV Unmanned Ground Vehicle tested in the field*, Army Recognition,* https://armyrecognition.com/mspo_2020_news_official_show_daily/mspo_2020_polish-made_perun_armed_ugv_unammed_ground_vehicle_tested_in_the_field.html, 11 September 2020. (Accessed on 12.10.2022)

of UMSs, Poland is also making progress, notably in USVs. The Polish government is in the process of procuring its navy with Double-Eagle SAROV USV, an undersea detection and mine-cleaning system.[689] In addition, the Polish navy plans to equip its new *Kormoran-class* mine countermeasure vessels with Gavia USVs, furnished with cutting-edge scan sonars to detect mines hidden in-depth.[690] This market is projected to increase to USD 18 million by 2025.

[689] Double Eagle SAROV: One system, multiple functions, *Saab Technologies*, https://www.saab.com/contentassets/33ba74f839b44ae3861195862e9d3f97/double_eagle_sarov_brochure.pdf. (Accessed on 12.10.2022)
[690] Gain, Nathan. Poland's MoD Procures Additional Gavia AUVs, *Naval News,* https://www.navalnews.com/naval-news/2020/07/polands-mod-procures-additional-gavia-auvs/, 4 July 2020. (Accessed on 11.10.2022)

Norway

Norway, a significant ally of NATO and a non-European Union member, has recently experienced a challenging strategic position due to the aggressive actions of Russia in Eastern Europe.[691] The Norwegian government spent between EURO 85 million and 121 million on military R&D in 2018, funds that are mainly monitored by the Norwegian Defence Research Establishment (Forsvarets – Forskningsinstitutt*,* FFI), the leading institution responsible for defence-related research in the country. Norway is an interesting case of study, because of its triangular model of defence innovation ecosystem, including FFI, the defence industry represented by the Association of Norwegian Defence Companies (Forsvars- og Sikkerhetsindustirens, FSi) and the Norwegian armed forces.[692] In recent years, the deterioration of Norway's strategic environment has prompted a reassessment of its primary objectives, which can be succinctly summarised as follows: (1) the revitalization of collaboration with NATO to guarantee credible deterrence and collective security, particularly in light of Finland’s and Sweden's accession, (2) the increasing importance of the High North with ice melting due to climate change, and the expected militarisation of this region by Russia[693], and (3) the rise of the salience of Nordic regional security cooperation, notably with NORDEFCO.[694]

Norway's tradition of maintaining a competent defence industry is a legacy of the Cold War and Oslo's unwillingness to rely entirely on allied and US exports to supply its armed forces.[695] Indeed, *“(…) the government underlines that a competitive defence industry is important for Norway, mainly due to factors like topography, climate and geographic location.”*[696] The main objective of the Norwegian defence industry is therefore to supply the national armed forces, although Norway also exports high-end niche products, such as the NASAMS missile defence system. The triangular collaboration of the FFI, FSi and armed forces takes the following form: *“FFI and the defence industry cooperate on product development, the industry and the Armed Forces work together on setting requirements, support in operations and commercial deliveries, while the Armed Forces and FFI cooperate on technical and operative evaluation and developing operational concepts.”*[697] In practice, this means that the FFI initiates and develops projects at low TRLs before handing them over to industry, which will replicate develop them at higher TRLs.[698] With this system, the largest defence companies, such as Kongsberg and Nammo – in which the state has a majority stake – can realise their full potential by being correctly guided by the FFI's recommendations and the military's technical assessments.[699]

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[691] Gramer, Robbie. NATO Doubles Naval Presence in Baltic, North Seas After Pipeline Sabotage, *Foreign Policy,* https://foreignpolicy.com/2022/10/11/baltic-nato-russia-navy-nord-stream-sabotage/, 11 October 2022. (Accessed on 12.10.2022)
[692] Hatlebakk Hove, Kjetil. “Defence Industrial Policy in Norway. Drivers and Influence”, *Armament Industry European Research Group (ARES)*, 2018.: 6.
[693] Gosselin-Mao, Elisabeth. Norway special operators field pitches on fresh, Arctic-capable gear, *Defense News*, https://www.defensenews.com/global/europe/2023/02/09/norway-special-operators-field-pitches-on-fresh-arctic-capable-gear/, 9 February 2023. (Accessed on 15.02.2023)
[694] Defence of Norway: Capability and Readiness, *Norwegian Ministry of Defence*, 2020.: 16.
[695] Berdal, Mats R. *The United States, Norway and the Cold War, 1954-60*. London: Palgrave Macmillan UK: Imprint: Palgrave Macmillan, 1997.: 28.
[696] Hatlebakk Hove, Kjetil. “Defence Industrial Policy in Norway. Drivers and Influence”, *Armament Industry European Research Group (ARES)*, 2018.: 3.
[697] *Ibid.*
[698] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
[699] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 316.

This results-oriented approach is useful in providing the sector with clear expectations and guidance, but it is also partly a hindrance to the innovation process, as most private companies expect FFIs to do the groundwork, rather than doing it themselves.[700] The triangular innovation system is nevertheless praised in Norway because it allows for short decision lines, frequent interactions, a focus on end-users, a high level of trust and good division of labour ensuring fruitful innovation.[701] The Norwegian defence industry is advanced and diverse, with a high part of SMEs and a combination of private and public-owned companies.[702] The document *Defence of Norway* points out to the significance of harnessing new technologies and stresses that *"(…) in order to take advantage of technological development in the civilian sector and to strengthen the national knowledge base, the defence sector will increase cooperation with academia and the business community."*[703] In terms of organisation, the MoD directly overhauls most things related to defence, which simplifies the administrative processes of R&D and procurement.[704]

This results-oriented approach is useful in providing the sector with clear expectations and guidance, but it partly hampers the innovation process, as most private companies expect FFIs to do the groundwork instead of doing it themselves.

A recent official document highlights the importance of innovation and technology in the process of modernising the Norwegian armed forces.[705] Norway spent between EURO 85 and 121 million in military R&D in 2018, which is close to the Netherlands, however with a national population three times smaller.[706] If Norway's defence-related innovation system and industrial base are mostly effective, the country's authorities are taking actions to yield new technologies to procure the armed forces with advanced capabilities. *"FFI has set up the Innovation and Industrial Development Division and ICE worx innovation centre* [to act as innovation incubators]*."*[707] FFI has four main research areas, among which autonomy and AI rank atop.[708] Since 2013, FFI has given priority to facilitating the maturation of platforms and systems to be adopted by the armed forces. FFI also continues to support and facilitate civil-military technology spin-offs, although these are relatively rare in the Norwegian context. Finally, FFI cooperates with third parties and countries.[709]

In terms of cooperation with other countries and organisations, Norway gives a clear priority to NATO programmes, and in particular has high expectations of new initiatives such as DIANA and INF. Norway will host a DIANA test centre focusing on robotics and autonomy.[710] At the same time, Norway has strong bilateral defence relations with the UK, the Netherlands and Germany, and cooperates in EU-funded projects. Oslo was the first non-EU member to

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[700] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
[701] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 326.
[702] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; The International Institute for Strategic Studies, 2022.: 133.
[703] Defence of Norway: Capability and Readiness, *Norwegian Ministry of Defence*, 2020.: 18.
[704] Hatlebakk Hove, Kjetil. "Defence Industrial Policy in Norway. Drivers and Influence", *Armament Industry European Research Group (ARES)*, 2018.: 5.
[705] Future Acquisitions for the Norwegian Defence Sector 2023-2030, *Ministry of Defence*, 2023.: 5.
[706] *Ibid*.: 6.
[707] Outlook: Research and development plan 2021–2024, *Norwegian Defence Research Establishment*, 2021.: 24
[708] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
[709] Outlook: Research and development plan 2021–2024, *Norwegian Defence Research Establishment*, 2021.: 31.
[710] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.

sign a cooperation agreement with the EDA in 2006 and is committed to further integration of the European defence industry. With regard to the remaining factors driving innovation: (1) innovation is increasingly recognised by the Norwegian authorities and the public as a predominant factor of strategic stability, (2) the triangular system of defence-related innovation is effective in this area and the government is leading important initiatives, and (3) investment in military R&D is high and has been sustained over a long period.

Although it has not updated its military doctrine since 2007, Norway has made progress in thinking about integrating military robotics and autonomous systems into its armed forces. As noted in an official document: *"(…) automation and robotisation will reduce the need for human labour in many industries in the future. (…) The goal of such efficiency improvements must be to ensure that soldiers are better supported and to free up manpower for important duties."*[711] Overall, applications for robots include ISR, logistics and transport, swarms of armed and unarmed systems, but not direct combat missions. Another FFI report contends that the armed forces are *"(…) progressing towards concepts in which autonomous systems and people complement each other."*[712] The integration of military robotics has even been developed at the operational and tactical levels, with the establishment of a Special Intelligence Battalion (SIB) within the air force, that works solely with UAVs. The FFI also released a video explaining the Base Defence Concept (BDC), which shows a group of UAVs, UGVs and UMSs integrated with human decision-makers and soldiers working together.[713] In addition, Norway is in the process of establishing four "Test & Experimentation Areas", where FFI and the defence industry will develop prototypes for the military and test them during exercises, thus reducing processes to a minimum.[714]

Platforms	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	65	87	100	123	22.5%
UGVs	6	14	19	22	54.4%
UMSs	3	6	13	18	82.2%
Total	**74**	**107**	**132**	**163**	**31%**

Figure 29 – Norway military robotic and autonomous systems market, USD million.[715]

711 Outlook: Research and development plan 2021–2024, *Norwegian Defence Research Establishment*, 2021.: 12.
712 *Ibid.*
713 Mathiassen, Kim. Unmanned ground vehicles for the Armed Forces - How can we use unmanned ground vehicles in the Armed Forces?, *Norwegian Defence Research Establishment*, https://www.ffi.no/en/research/unmanned-ground-vehicles-for-the-armed-forces, 2018. (Accessed on 13.10.2022)
714 Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
715 Figure made by the authors. *Sources:* Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews.

Like several European countries, Norway has been using UAVs for at least a decade, and an official document highlights the fact that autonomous systems were defined as a priority as early as 2013.[716] Figure 29 shows Norway's market size for each type of military robotics. The Norwegian armed forces have tested the Black Hornet Nano drone and are reportedly in the process of acquiring it.[717] FFI and the air force have also conducted a market study to obtain VTOL UAVs. In addition, Norway operates American-made RQ12A Wasp Block IV and RQ-20B Puma AE II drones (Table 7). There are however no indigenous types of UAVs. The Norwegian UAV market is expected to grow from USD 65 million to 123 million by 2025.

In the field of UGVs, Norway has bought and fielded several THeMIS systems from Milrem Robotics.[718] Oslo is providing its armed forces and police units with the Packbot Ground Robot, a lightweight UGV that can detect chemical and nerve agents and defuse explosives.[719] A video released by FFI showed the armed forces operating a UGV called Olav, driving autonomously, and carrying a machine gun.[720] The UGV market in Norway is projected to reach USD 22 million by 2025, witnessing a significant increase. For unmanned maritime systems, Norway fields both imported models and indigenously produced systems: the REMUS 100 UUV by Huntington Ingalls Industry, and the Reach Subsea, the Hugin UUV and the Odin USV, produced by Kongsberg.[721] The maritime domain is the priority for Norway, as most of the threats facing the country would come from the seas.[722] So far, the Norwegian navy primarily intends to task unmanned maritime robots with counter-mine measures and anti-submarine warfare. The new MCMV 47 and 52 *Koster-Class* ships designed for the navy will embark some of these systems, and work with them, following the MUM-T principle.[723] The UMSs market is expected to increase from USD 3 million in 2022 to 18 million by 2025.

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[716] Outlook: Research and development plan 2021–2024, *Norwegian Defence Research Establishment*, 2021.: 25.
[717] Saballa, Joe. Norway Purchases Teledyne FLIR Black Hornet Nano Drones, *The Defense Post,* https://www.thedefensepost.com/2022/06/24/norway-teledyne-hornet-drones/, 24 June 2022. (Accessed on 14.10.2022)
[718] Gray, Maggie and Ertan, Amy. "Artificial Intelligence and Autonomy in the Military: An Overview of NATO Member States' Strategies and Deployment: Overview document and Appendix A (Country Profiles)", *NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE)*, 2021.: 26-27.
[719] FLIR to equip Norway Defense and Police with Packbot Ground Robots, *CBRNE Central*, https://cbrnecentral.com/flir-to-equip-norway-defense-and-police-with-packbot-ground-robots, 9 September 2019. (Accessed on 13.10.2022)
[720] Mathiassen, Kim. Unmanned ground vehicles for the Armed Forces - How can we use unmanned ground vehicles in the Armed Forces?, *Norwegian Defence Research Establishment*, https://www.ffi.no/en/research/unmanned-ground-vehicles-for-the-armed-forces, 2018. (Accessed on 13.10.2022)
[721] Kongsberg Maritime: New Norwegian Autonomous Shipping Test-Bed Opens, *Saltwalter Stone,* https://www.kongsberg.com/maritime/about-us/news-and-media/news-archive/2017/new-norwegian-autonomous-shipping-test-bed-opens, 7 December 2017. (Accessed 14.10.2022)
[722] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
[723] Mine Counter Measure Vessels (MCMV), *Saab,* https://www.saab.com/products/mine-counter-measure-vessels, 23 September 2020. (Accessed on 14.10.2022)

Sweden

Until recently, Sweden's foreign and security policy was *"(…) integration-oriented, EU-based solutions to security problems and commit to them on an institutional basis to build credibility with friendly states and deter unfriendly ones."*[724] Since 2020, the successive shocks of COVID-19 and Russia's aggression against Ukraine have triggered a national debate on the country's strategic direction. While this phenomenon is not entirely new, as Stockholm officially relaunched its *Total Defence Concept* (TDC) in 2015, it is only recently that Sweden has truly revised its security strategy. In October 2020, the Defence Bill for 2021-2025 was voted on, allowing for higher military spending and an expansion of the armed forces' capabilities.[725] Russia's aggressive activities in the Baltic Sea, coupled with its invasion of Ukraine in 2022, finally convinced Stockholm to join NATO, a process that is currently underway at the end of 2023.[726] This challenging regional environment explains that Sweden spends EURO 90.6 million on defence-related R&D and 30 million through its two programs, *Robodalen* and the *Framework Grants for Research on Smart Systems*, focused in defence-related robotics programs.

Sweden's national defence architecture is similar to Norway's. It is composed of three main institutions in addition to the armed forces: the Swedish Defence Research Agency (Försvarets forskningsanstalt, FOI), the Swedish Defence University (Försvarshögskolan, FHS), and the Defence Material Administration (Försvarets Materielverk, FMV). Such a framework is intended to facilitate the implementation of Sweden's whole-of-society approach as envisaged in the TDC and to respond to Stockholm's three foreign and security policy priorities: (1) sustained military cooperation with the US, UK, NORDEFCO and NATO partners to ensure collective security to deter aggressive actors, (2) securing EU consensus on economic, political and, increasingly, defence issues to stabilise Sweden's domestic prosperity, and (3) renewing Sweden's prominence as a humanitarian power despite formally abandoning neutrality following the decision to join NATO.[727]

Sweden has a long tradition of innovation and scientific discovery. In addition, Sweden is historically one of the most important defence players, having been a major European military power between the 16th and 19th centuries, dominating most of the countries bordering the Baltic Sea. Such an ambitious foreign policy therefore required a significant defence production capacity: Bofors, founded in 1646 to equip the Royal Swedish Navy, and Akers Krutbruk, founded in 1552, were among the first defence companies in Europe.[728] This trend continues today, with the defence industry being the most technology- and capital-intensive sector in Sweden.[729] Simultaneously, this observation highlights the primary characteristic of

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724 Bynander, Frederik. "Sweden's Security Policy after Covid-19", *Prism,* Volume 9, No. 4, 2022.: 86.
725 Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS)*, 2022.: 151.
726 When will Sweden and Finland join NATO? Tracking the ratification process across the Alliance., *The Atlantic Council,* https://www.atlanticcouncil.org/commentary/trackers-and-data-visualizations/when-will-sweden-and-finland-join-nato-tracking-the-ratification-process-across-the-alliance/, 27 September 2022. (Accessed on 17.11.2022)
727 Main elements of the Government bill – Total defence 2021–2025, Government of Sweden, *Ministry of Defence*.: 79.
728 Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 290-291.
729 Defence innovation – A Swedish perspective, *Swedish Security & Defence Industry Association (SOFF),* 2020.: 13.

Sweden's defence industry: namely its significant size and diversity for a country of 10 million inhabitants.[730]

> *As of 2022, Sweden is one of the few states to be able to domestically produce high-end items such as anti-air defence systems and conventional submarines. The secondary characteristic of Sweden's defence industrial basis is its export-oriented inclination and the fact that it is composed mainly of private firms (…)*

Because of its neutrality, formally declared in 1834, Sweden has long since decided to maintain domestic development and production capabilities in the field of defence in order to remain militarily non-aligned.[731] That explains partly why Sweden hosts industry behemoths such as BAE Systems or Bofors and how such global military equipment stars as the CV90 IFV, the Archer self-propelled howitzer and the PSG-08 sniper rifle are all of Swedish conception.[732] As of 2022, Sweden is one of the states to be able to domestically produce high-end items such as anti-air defence systems and conventional submarines.[733] Sweden's accession to NATO means that this policy of neutrality has now come to an end, but given the importance and performance of its defence industry, Stockholm will seek to maintain and even expand it. The second characteristic of the Swedish defence industrial base is its export-oriented nature and the fact that it consists mainly of private companies, a significant proportion of which are foreign-owned (mainly by British and US groups).[734]

In organisational terms, the triangular cooperation between FOI, FMW and FHS permits a fruitful division of labour: FOI is in charge of conducting policy research and drafting recommendations, FMV buys and procures equipment for the armed forces and FHS is mandated to develop, test and select items.[735] FOI has significant means, as it employs around 1'100 people, 900 of which are researchers. This institution does not immediately depends from the Swedish MoD, as it receives funding from various ministries and state agencies to conduct research.[736] The main difference with the Norwegian system is the importance of another institution, the Swedish Security and Defence Industry Association *(Säkerhets- och försvarsföretagen,* SOFF) tasked to defend the interest of the mighty Swedish defence industry.[737] This institution is committed to lobby policymakers in Stockholm and Brussels to make sure that the Swedish defence industry remains at the top. Considering the other factors driving innovation: (1) innovation is recognised as an important strategic factor, but decades of relative neglect of the military have had negative consequences, (2) the division of labour between different institutions works well to develop new systems and defend the interests of

[730] Lundmark, Martin. "The Evolution Towards the Partial Strategic Autonomy of Sweden's Essential Security Interests." *Defence and Peace Economics*, No. 4, May 19, 2022.: 392.
[731] Czarny, Ryszard M. *Sweden: From Neutrality to International Solidarity*. 1st ed. 2018. Cham: Springer International Publishing: Imprint: Springer, 2018.
[732] List of equipment of the Swedish Army. *Wikipedia*, https://en.wikipedia.org/wiki/List_of_equipment_of_the_Swedish_Army. (Accessed on 18.11.2022)
[733] Sweden's Submarine Capabilities, *The Nuclear Threat,* https://www.nti.org/analysis/articles/sweden-submarine-capabilities/, 17 February 2021. (Accessed on 18.11.2022)
[734] Schmidt-Felzman, Anke. "PeSCO – A Swedish Perspective", *Armament Industry European Research Group (ARES),* March 2019.: 11.
[735] Lundmark, Martin. "The Evolution Towards the Partial Strategic Autonomy of Sweden's Essential Security Interests." *Defence and Peace Economics* 33, No.4, May 19, 2022.: 395.
[736] Interview at the Swedish Defence Research Agency (FOI), 27 March 2023.
[737] Schmidt-Felzman, Anke. "PeSCO – A Swedish Perspective", *Armament Industry European Research Group (ARES),* March 2019.: 2.

the defence industry, and (3) investment in military R&D is satisfactory and likely to increase in the foreseeable future.[738]

In 2021, Sweden's defence spending amounted to USD 7.54 billion and the government added 300 million to the 2022 budget.[739] Between 1-1.2% is invested in defence-related R&D which places Sweden in the continental medium. It is believed that Sweden invests around EURO 30 million a year in R&D of robotics. The *2020 Defence White Book* mentions massive investments in conventional capabilities for the 2021-27 period: armoured vehicles, howitzers, multiple rocket launchers and submarines, but does not mention military robotics.[740] This document also highlights the fact that R&D in the field of defence needs more resources.[741]

Given the nature of Stockholm's defence industrial base, a closer look at supranational military cooperation programmes is indicative of the country's overall defence development. With regard to EU cooperation instruments, Sweden could be described as a relatively supportive but cautious actor. Stockholm has always taken a positive view of the emergence of PESCO, especially its inclusive nature, bringing together 25 of the 28 member states and seeking consensus.[742] PESCO is seen as an instrument to foster greater European unity against shared challenges (mainly Russia) and a potential bridge towards non-EU NATO members such as the UK and the US: *"The closer coordination on defence between the EU and NATO is in that context explicitly desired and of particular importance to Sweden."*[743] But Sweden's participation in EU-led defence projects also illustrates the country's difficult balancing act between its main pole of economic interest, the EU, and its traditional security partners, the US and the UK.[744] This explains why Sweden has been cautious in its participation in the EDF, considering that the scope of the fund is too narrow as it does not include London (since Brexit) and henceforth does not cover the whole of the Swedish defence industry's interests. As a matter of fact, *"(…) there is a risk that current initiatives would reduce incentives for European cooperation with the US and post-Brexit UK."*[745]

Despite this strategic caution, Swedish policymakers recognise that the fragmentation of the European defence market hampers competition and cost-efficiency, and that the EDF is a necessary development. As one official paper puts it: *"It is in Sweden's interest that the work programmes of the European Defence Fund (EDF) meet Swedish capability needs and therefore is relevant both for the government as well as for Swedish companies and research institutes."*[746] In many ways, Sweden's accession to NATO and the organisation's progressive development of its own capabilities to conduct defence R&D through instruments such as DIANA and the INF are converging factors that should support Stockholm's objectives. Already an important NATO partner – Stockholm joined the Partnership for Peace (PfP) in 1994 and is part of the Partnership Interoperability Initiative (PII) and the Planning and Review Process

[738] Main elements of the Government bill – Total defence 2021–2025, Government of Sweden, *Ministry of Defence*.: 131.
[739] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; The International Institute for Strategic Studies, 2022.: 151.
[740] Lundmark, Martin. "The Evolution Towards the Partial Strategic Autonomy of Sweden's Essential Security Interests." *Defence and Peace Economics* 33, No.4, May 19, 2022.: 406.
[741] Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 299.
[742] Schmidt-Felzman, Anke. "PeSCO – A Swedish Perspective", *Armament Industry European Research Group (ARES)*, March 2019.: 5-6.
[743] *Ibid.:* 8.
[744] Interview at the Swedish Defence Research Agency (FOI), 27 March 2023.
[745] Olsson, Per. "National Expectations Regarding the European Defence Fund: The Swedish Perspective", *Armament Industry European Research Group (ARES),* October 2019.: 4.
[746] Materielförsörjningsstrategi För vår gemensamma säkerhet (SOU 2022:24), *Betänkande av Materielförsörjningsutredningen*, Stockholm 2022.: 28.

(PRP) – Sweden's imminent accession to the transatlantic security organisation will certainly help to smooth its position between Brussels and Washington.[747]

In terms of doctrine, it is difficult to assess the role that the Swedish Armed Forces would assign to robotics, as official documents do not mention autonomous systems and robots, and Sweden is not advanced in fielding these systems.[748] As mentioned above, Swedish authorities have announced a comeback to the Cold War-era *Total Defence Concept*: *"Swedish military thinking has once again returned (…) to the idea of defending its territory in the face of an attack by a hostile external state actor, and it has been expressed in recent doctrine publications such as Militärstrategisk Doktrin (MSD16) and Doktrin för Gemensamma Operationer (DGO 20)."*[749] The concept notes that in an age of renewed Russian expansionism, strengthening conventional capabilities is the surest way to ensure Sweden's national integrity and sovereignty, but makes no mention of autonomous weapons or robots.[750] Nevertheless, the specific priorities identified by the TDC provide possible indications of the likely future development of military robotics for the Swedish Armed Forces. For example, when it mentions anti-submarine and ISR as urgent capabilities to be strengthened, we can imagine that Swedish military decision-makers are aware that these tasks can increasingly be delegated to UMS and UAVs.[751] As one expert stresses *"Keeping up with the pace of development is a challenge for the Swedish Armed Forces."*[752], and if this can look curious for a country with such advanced defence industry as Sweden, it is now clear that decades of relative disinterest for everything strategic hinders Sweden's material capabilities as well as its doctrinal thinking.

Platforms	**2022**	**2023**	**2024**	**2025**	**CAGR (2020-2025)**
UAVs	60	76	87	101	19%
UGVs	9	13	17	23	36.7%
UMSs	4	5	7	9	31.6%
Total	**73**	**94**	**111**	**133**	**22.3%**

Figure 30 – Sweden military robotic and autonomous systems market, USD million.[753]

[747] Relations with Sweden, *North Atlantic Treaty Organization (NATO),* https://www.nato.int/cps/en/natohq/topics_52535.htm, 26 September 2022. (Accessed on 18.11.2022)
[748] Militärstrategisk Doktrin (MSD22), *Försvarsmakten,* Stockholm, 2022.
[749] Finlan, Alastair. "The shape of warfare to come: a Swedish perspective 2020–2045", *Defense & Security Analysis*, Vol. 37 No. 4, 2021.: 483.
[750] Objectives for Swedish total defence 2021–2025 - Government bill 'Totalförsvaret 2021–2025', *Government Offices of Sweden,* https://www.government.se/government-policy/defence/objectives-for-swedish-total-defence-2021-2025---government-bill-totalforsvaret-20212025/, 18 December 2020. (Accessed on 18.11.2022)
[751] Main elements of the Government bill Totalförsvaret 2021–2025, *Government Offices of Sweden,* https://www.government.se/49648a/globalassets/government/dokument/forsvarsdepartementet/ip-2021-2025/main-elements-of-the-government-bill-totalforsvaret-20212025.pdf, 12 December 2020. (Accessed on 18.11.2022)
[752] Steinvall, Anders. "Technology of the future requires swift decisions in Defence Innovation – A Swedish Perspective", *Swedish Security & Defence Industry Association (SOFF)*, 2021.: 4.
[753] Figure made by the authors. *Sources*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A

Figure 30 highlights the respective market size of each type of robotic systems in Sweden. In the aerial domain, the Swedish military possesses four different types of small US-made UAVs: RQ-20 Puma, the RQ-12 Wasp as well as the RQ-7 Shadow; an Israeli-manufactured type of UAV, the Skylark I LE; and the partly locally produced Skeldar VTOL (Table 7).[754] The UAV market is projected to reach USD 101 million by 2025, up from 60 million in 2022. Noticeable is the fact that Sweden, in opposition to Norway or Finland, does not possess MALE or HALE UAVs, especially well designed for ISR missions in contested environments such as the Baltic Sea. This demonstrates how far Sweden has fallen behind and explains the insistence of Swedish defence officials to scale up investment in emerging technologies.[755] FOI is nevertheless conducting research on new drone capabilities for the armed forces.[756]

The UGV market in Sweden is not particularly developed, but as the armed forces intend to develop indigenous production capabilities in this domain, it is projected to grow to USD 23 million by 2025. In the maritime domain, *"The challenge for the Swedish Navy today is whether its traditional defensive posture and force structure to defend Sweden is still optimal in the age of hypervelocity weapons and unmanned drones in the air and at sea."*[757] The recent acquisition of two new *Blekinge*-class submarines indicates that Sweden still gives priority to conventional maritime capabilities.[758] Sweden is currently developing five different UMSs: the Bonefish USV in collaboration with Indonesia, the Enforcer III, the Piraya, the SAM 3 and the CB-90 Optionnally Manned USV, all from SAAB (see Table 9). Its UMS market is expected to grow from USD 4 million to 9 million by 2025.

Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews.

[754] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.: 157.

[755] Sweden embarks on its largest military build-up for decades, *The Economist,* https://www.economist.com/europe/2020/10/19/sweden-embarks-on-its-largest-military-build-up-for-decades, 19 October 2020. (Accessed on 17.11.2022)

[756] Interview at the Swedish Defence Research Agency (FOI), 27 March 2023.

[757] Finlan, Alastair. "The shape of warfare to come: a Swedish perspective 2020–2045", *Defense & Security Analysis*, Vol. 37 No. 4, 2021.: 483.

[758] Saab Receives Further Order for the A26 Submarine for Sweden, *Saab,* https://www.saab.com/newsroom/press-releases/2021/saab-receives-further-order-for-the-a26-submarine-for-sweden, 27 August 2021. (Accessed on 14.10.2022)

Estonia

Estonia's existence was continuously threatened by its neighbours between the 15th and 20th centuries.[759] Such a historical legacy explains the current Estonian mindset when it comes to defence: the country needs a national military deterrent, but it ultimately *"(…) is reliant on NATO membership as a security guarantor."*[760] As a result, Tallinn's accession to NATO in March 2004 marked a radical shift in the country's foreign and security policy. It is therefore not surprising that Estonia is one of the most pro-Atlantic and pro-European countries, not afraid to take an active stance, being the only Baltic state to participate in external peacekeeping missions such as Barkhane and the French-led Takuba Task Force under the auspices of the European Intervention Initiative (EII). Simulataneously, Estonians were among the first to warn Western policymakers about the return of Russian aggressiveness, seeing Moscow's massive cyber-attacks on Estonia's IT grid in 2007 and its initial aggression against Ukraine in 2014 as prologues of more to come.[761] As one recent official report puts it: *"The only existential threat to the security of our region, including Estonia's sovereignty, stems from Russia."*[762] Alongside its Baltic partners, Estonia advocated at the NATO Madrid Summit of 2022 that "deterrence by punishment" failed and that the alliance ought to implement a strategy of "deterrence by denial", or "forward defence".[763]

In terms of numbers, Estonia is increasing its military spending, with a defence budget of USD 658 million in 2021, amounting to 2.35% of its GDP.[764] The year 2022 marks the beginning of a new era, as the Estonian government has announced an annual budget increase of 18% to USD 801 million.[765] Remarkably, Estonia is, in comparison to its size, the country that has aided Ukraine the most, with an overall defence assistance worth USD 311 million (as of May 2023) which represents more than 40% of its yearly defence budget.[766] In 2020, Estonia spent EURO 4.4 million in defence-related R&D, which logically makes of the Baltic country the smallest spender of the list.[767] However, Tallinn's success in countering Russian cyber-attacks and its growing military potential explain why Estonia is an interesting case study when it comes to defence innovation and the development of military robotics. Overall, Estonia's foreign and security policy is based on three pillars: (1) ensuring credible deterrence in the face of Russian military threats through a strong commitment to NATO, the EU's CSDP and regional partnerships such as the UK-led Joint Expeditionary Force and the Three Seas Initiative (3SI); (2) supporting the EU's political and economic framework as well as other international institutions that maintain global stability: the UN, the OSCE, the WTO and the

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[759] Frucht, Richard C., ed. *Eastern Europe: An Introduction to the People, Lands, and Culture / Edited by Richard Frucht*. Santa Barbara, Calif: ABC-CLIO, 2005.: 75.
[760] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS)*, 2022.: 100.
[761] Maigre, Merle. "Estonia: In Pursuit of a Value-Based Foreign Policy." *German Marshall Fund of the United States*, 2015.: 16–20.
[762] International Security and Estonia 2023, *Estonian Foreign Intelligence Service*, 2023.: 11.
[763] Lawrence, Tony. "Estonia". In: Mölling, Christian et al. "European Defense in A New Age (#EDINA) – Geostrategic Changes and European Responses Shaping the Defense Ecosystem", *Deutsche Gesellschaft für Auswärtige Politik (DGAP),* June 2023.: 16.
[764] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS)*, 2022.: 100.
[765] Defence Budget, *Ministry of Defence*, Republic of Estonia, https://kaitseministeerium.ee/en/objectives-activities/defence-budget, 7 July 2022. (Accessed on 24.11.2022)
[766] Ukraine Support Tracker, *The Kiel Institute for World Economy (IFW)*, https://www.ifw-kiel.de/topics/war-against-ukraine/ukraine-support-tracker/?cookieLevel=not-set, Update 4 April 2023. (Accessed on 15.05.2023)
[767] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS*); Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022, Factsheet: Estland: 1.

OECD, and (3) raise Estonia's profile by building on its strengths, such as e-government, cybersecurity, a competitive business environment and a rich cultural heritage.[768]

Estonia has long understood the need to harness technological innovation to strengthen its defence capabilities.[769] As General Riho Terras, former commander of the Estonian armed forces, summed it up: *"Due to rapid technological developments, the importance of defence research and innovation is growing and it should be treated as one of the key elements that shapes the design of defence, and it is of importance for the Baltic states to acknowledge this fact."*[770] Importantly, Estonia is one of the most innovative countries in the world.[771] However, due to the small size of the market, national demand for cutting-edge innovation products is limited. As a result, Estonia relies heavily on a network of local SMEs developing dual-use technologies that are identified and supported by the state, be it the MoD or the Ministry of Entrepreneurship and Information Technology.

The Estonian Defence and Aerospace Industry Association (EDAIA), the Department of Applied Research of the Military Academy (DAR) and the Estonian Centre for Defence Investment (ECDI) are the principal organisations coordinating government efforts.[772] This architecture is highlighted in the *R&D Policy and Defence industrial Policy 2013-2022*, Estonia's guiding document to organise R&D, procurement and fielding of military capabilities.[773] EDAIA provides a platform between industry, R&D organisations and most government actors to finance and design defence-related projects, as well as to support the export of Estonian military equipment. A good example of EDAIA's work is the successful establishment of the Defence Estonia Cluster in 2019, which specialises in AI, C2, UAVs and autonomous systems and aims to increase the country's defence exports tenfold by 2029.[774] EDAIA also houses European companies, such as SAAB, MBDA, and BAE Systems, Raytheon Technologies from the US, and Japan's Fujitsu. DAR, on its side, bridges the Estonian armed forces with technologies developers in order to mature field-proven material suitable to the soldiers' needs.[775] It also links the different defence actors together, smoothen processes and provide recommendations to the military.[776] ECDI was created in 2017 to centrally manage the organisation of defence procurement and therefore orient funds dedicated to acquisition of innovative solutions more effectively.[777] In addition to these government agencies, two types of organisations are involved in defence-related innovation: competence incubators, such as Start Up Estonia, and research laboratories at the Tallinn University of Technology and the University of Tartu.[778]

This dense administrative architecture of defence innovation covers all stages from management impulses to commissioning and testing of capabilities, allowing Estonia to be

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[768] Estonian Foreign Policy Strategy 2030, *Ministry of Foreign Affairs,* Republic of Estonian, 2020.: 8-9.; 11-15.
[769] Jermalavicius, Tomas and Hurt, Martin. "Defence Innovation: New Models and Procurement Implications. The Estonian Case", *Armament Industry European Research Group (ARES)*, 2021: 2.
[770] Andžāns, Māris. "Digital Infantry Battlefield Solution: Concept of Operations: Part Two", *Latvian Institute of International Affairs*, 2017.
[771] Global Innovation Index 2022, 15th Edition What Is the Future of Innovation Driven Growth?, *World Intellectual Property Organization*, 2022.: 19.
[772] Interview with the Innovation Department, *Estonian Ministry of Defence*, 20 April 2023.
[773] Defence Industry Policy 2013-2022, *Ministry of Defence*, Republic of Estonia, February 2018.
[774] Jermalavicius, Tomas and Hurt, Martin. "Defence Innovation: New Models and Procurement Implications. The Estonian Case", *Armament Industry European Research Group (ARES)*, 2021.: 9.
[775] Department of Applied Research, *Estonian Military Academy*, https://www.ksk.edu.ee/en/research/centre-for-applied-studies/. (Accessed on 23.11.2022)
[776] Interview with the Innovation Department, Estonian Ministry of Defence, 20 April 2023.
[777] Defence Procurement, *Centre for Defence Investment*, https://www.kaitseinvesteeringud.ee/en/defence-procurement/. (Accessed on 23.11.2022)
[778] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS); *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022, Factsheet: Estland: 1.

both flexible and responsive in its military procurement: *"With this, Estonia addressed the need to enhance its technology management capacity and created the framework to better integrate defence innovation and procurement processes."*[779] The Estonian defence complex relies heavily on the spill-over from the civilian domain, what policymakers call the Comprehensive Approach – similar to Sweden's Total Defence Concept – which could be described as follows: *"In Estonia, the society carries the military forward."*[780] This is largely possible because military applications do not have a bad reputation in Estonia, and many private companies working on dual-use technologies are interested in helping to develop the armed forces' capabilities. Estonia's conscription system also means that the majority of the population has military experience and understands the importance of ensuring the country's self-defence capabilities.[781] Regarding the other factors driving innovation: (1) defence innovation is a central part of Estonia's security strategy, (2) the dense system of institutions co-developing military equipment with private actors is efficient despite the limited size of the Estonian market, and (3) investment in defence R&D is important given Estonia's size, but the country still relies heavily on EU and NATO initiatives.

Regarding Estonia's position in supranational defence R&D and procurement projects, Tallinn has watched the development of EU and NATO instruments with an interested but cautious eye. In this regard, the recent transatlantic tensions, especially during the Trump presidency, have created a dilemma for Tallinn between what it sees as its community of values and most important market, namely the EU, and its indispensable security guarantor, the US and NATO. As one expert puts it: *"European security is built on the transatlantic alliance and strong transatlantic link is the highest national security priority for Estonia."*[782] In the light of the transformation of the geopolitical system, Estonia has increasingly seen the added value of PESCO, EDF and EDIDP as vectors for the development of new capabilities to address hybrid threats. For example, Estonia is leading the iMUGS project, an EDIDP-funded consortium bringing together German, Belgian, Finnish, French and Spanish companies to develop a range of multi-purpose hybrid manned-unmanned systems.[783] Estonia is also a key actor in the development of the Medium Size Semi-Autonomous Surface Vessel (M-SASV) through the framework of EDF.[784] Historically, Estonia has privileged large procurements from US sources, notably because of the better price/quality ratio of US products. Yet, political calculus is never far-off from this kind of decision.[785]

To manage this difficult balance, Estonia has sought to participate in a dozen EU-funded defence projects and is exploring the possibility of joining other minilateral formats such as the "Plus Initiative" (Poland-Lithuania-US).[786] It is likely that Estonia will pursue this path of pragmatic strategy for military procurement, seeking both cost-effective solutions and

[779] Jermalavicius, Tomas and Hurt, Martin. "Defence Innovation: New Models and Procurement Implications. The Estonian Case", *Armament Industry European Research Group (ARES)*, 2021.: 8.
[780] Ispas, Irina. "Principle of Military Innovation as an Upgrade to the Army Concept: Differences, Similarities and Lessons. A Case Study of Israel and Estonia.", Master's Thesis*, Tallinn University of Technology, Faculty of Social Sciences, Ragnar Nurkse School of Innovation and Governance*, 2019.: 33.
[781] Interview with the Innovation Department, Estonian Ministry of Defence, 20 April 2023.
[782] Seselgytè, Margarita. "Armament and Transatlantic Relationships: The Baltic States Perspective", *Armament Industry European Research Group (ARES)*, 2019.: 3.
[783] Jermalavicius, Tomas and Hurt, Martin. "Defence Innovation: New Models and Procurement Implications. The Estonian Case", *Armament Industry European Research Group (ARES)*, 2021.: 18.
[784] Interview with the Innovation Department, Estonian Ministry of Defence, 20 April 2023.
[785] Seselgytè, Margarita. "Armament and Transatlantic Relationships: The Baltic States Perspective", *Armament Industry European Research Group (ARES)*, 2019.: 6.
[786] Jeglinskas, Giedrimas and Hodges, Ben. Kościuszko's legacy for the world of tomorrow, *15 Minutes,* https://www.15min.lt/en/article/society/kosciuszko-s-legacy-for-the-world-of-tomorrow-528-1162898, 20 June 2019. (Accessed on 23.11.2022)

diplomatic gains. Nevertheless, it is obvious that Estonia will continue prioritising NATO initiatives and projects over those of the EU, as the transatlantic alliance represents its ultimate security guarantee.[787]

This dense administrative architecture of defence innovation covers all stages, from managerial impetus to commissioning and testing of capabilities, allowing Estonia to be both flexible and responsive in its military procurement.

So far, Estonia has not defined a doctrine on how it intends to integrate and use military robotic systems. The main reason for this is the fact that Estonia's military thinking has been influenced by three different concepts of warfare since the country first became independent in 1918. Firstly, pre-Soviet "forest warfare" à la Finland, based on counter-attacks and ambushes; secondly, Soviet-era tactics based on sheer mass and artillery; and thirdly, the current era of NATO membership, during which the Estonians have learnt Western approaches.[788] As a result, Estonia's military doctrine and strategy are still evolving: for example, it is in the process of adopting NATO's Standardisation Agreements (STANAG), while still relying on officers trained during the Soviet era.[789] In this context, the Estonian armed forces prioritise adaptability over doctrinal dogmatism, and this also applies to the use of military robotic systems. Robots are both a way for Estonia to increase armed deterrence and to virtually replace human personnel, but the armed forces will only use these systems if they increase the effectiveness of the armed forces.[790]

According to the *Estonia National Security Concept 2017*, these developments intrinsic part of the whole-of-society line at the heart of the Comprehensive Approach.[791] Recent decisions taken by the Estonian government seems to verify this assessment, as Tallinn decided to pursue a massive effort of modernisation of its armed forces: *"(…) the Estonian government understood that it would need to invest significantly in shoring-up domestic defence capabilities (…) to stood up any chance of competing in an armed conflict with the Russian federation."*[792] The document *Estonian Military Defence 2026* highlights that current mine countermeasure assets will be partly replaced by unmanned systems and that military intelligence and early warning tasks could be performed by drones.[793] The doctrinal thinking on military robotics is most advanced in the field of UAVs, as the Estonian have used them in external operations, but it is also advancing for UGVs and UMSs.[794]

The Estonian armed forces operate various types of unmanned military systems, and the national defence industry is accelerating the process of acquiring autonomous systems. Like other European countries, Estonia has been using UAVs for a long time. Tallinn operates American-made models such as RQ-20B Puma 3 (since 2019) and RQ-11 RAVEN (since

[787] Interview with the Innovation Department, Estonian Ministry of Defence, 20 April 2023.
[788] Veebel, Viljar, and Illimar Ploom. "Estonia's Comprehensive Approach to National Defence: Origins and Dilemmas." *Journal on Baltic Security* 4, No. 2, 2018, 10–22.
[789] Ispas, Irina. "Principle of Military Innovation as an Upgrade to the Army Concept: Differences, Similarities and Lessons. A Case Study of Israel and Estonia.", Master's Thesis*, Tallinn University of Technology, Faculty of Social Sciences, Ragnar Nurkse School of Innovation and Governance*, 2019.: 26.
[790] Interview with the Innovation Department, *Estonian Ministry of Defence*, 20 April 2023.
[791] Estonia National Security Concept 2017, Republic of Estonian, *Ministry of Defence*, 2017.: 11.
[792] The Modernisation of the Estonian Defence Forces, *Army Technology*, https://www.army-technology.com/comment/modernisation-estonian-defence-forces/, 30 March 2022. (Accessed on 24.11.2022)
[793] Estonian Military Defence 2026, Republic of Estonia, *Ministry of Defence*, 2019.: 2.
[794] Interview with the Innovation Department, Estonian Ministry of Defence, 20 April 2023.

2010).[795] However, Estonia also has local production capabilities in this field, notably with Threod Systems, a company that has become a world leader in innovative UAV technologies, especially in ISR, multi-rotor mini-UAVs and multi-purpose systems.[796] Threod's Stream C UAV is used to monitor illegal border crossings by the Estonian police and will soon be procured to the 2nd Infantry brigade of the armed forces.[797] Estonia's UAVs market is expected to grow from USD 37 million in 2022 to 65 million by 2025.

Platforms	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	37	48	56	65	20.7%
UGVs	6	8	11	14	32.9%
UMSs	3	6	8	11	54.2%
Total	**46**	**62**	**75**	**90**	**25.1%**

Figure 31 – Estonia military robotic and autonomous systems market, USD million.[798]

Estonia is a leader in UGVs, riding on the success of its champion: Milrem Robotics. The Estonian company has sold its THeMIS to 16 countries around the world and has been able to modify its products into an extremely versatile system thanks to the numerous feedbacks from tests during military exercises.[799] Overall, THeMIS can be used for almost all military-related settings with its different suits: offensive combat, tactical ISR, anti-tank warfare, target acquisition, combat engineering and bomb disposal, mine clearing, CBRN detection, communication relay, drone dropping, troop transport, logistics, etc.[800] Besides, Milrem's second UGV, the Type X, is likely to become the firm's rising star in the future, as *"(…) it is the first combat vehicle that is purposefully designed to be unmanned intended to be an integral part of mechanized units."*[801] Armed with a powerful 30mm cannon, heavily armoured and equipped with the latest generation of sights, the Type X is controlled by both an AI system and a remote operator. It is said to be the perfect complement to both a formation of regular tanks and a group of unmanned systems. In addition, Milrem is actively working with foreign companies to improve and develop other products, such as Turkey's Otokar and Norway's

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[795] Gray, Maggie and Ertan, Amy. "Artificial Intelligence and Autonomy in the Military: An Overview of NATO Member States' Strategies and Deployment: Overview document and Appendix A (Country Profiles)", *NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE)*, 2021.: 24.

[796] Threod Systems – Unmanned Aircraft Systems for the Defence Industry, *Army Technology,* https://www.army-technology.com/contractors/unmanned_vehicles/threod-systems/. (Accessed on 25.11.2022)

[797] Ball, Mike. UAS Monitors Estonia-Latvia Border for Illegal Crossings, *Unmanned Systems Technology,* https://www.unmannedsystemstechnology.com/2020/05/threod-systems-uas-monitors-estonia-latvia-border/, 17 May 2020. (Accessed on 24.11.2022)

[798] Figure made by the authors. *Sources:* Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Interviews.

[799] Haas, Michael. "Projektdokumentation «Robotik in den Streitkräften" Attn.: Swiss Drone and Robotics Centre (SDRC DDPS); *Center for Security Studies (CSS)*, ETH Zürich (ed.), 2022, Factsheet: Estland: 2.

[800] Andžāns, Māris. "Digital Infantry Battlefield Solution: Concept of Operations: Part Two", *Latvian Institute of International Affairs*, 2017.

[801] Milrem Robotics revealed Type-X RCV with John Cockerill CPWS II turret, *Milrem Robotics,* https://milremrobotics.com/milrem-robotics-revealed-type-x-rcv-with-john-cockerill-cpws-ii-turret/, 18 June 2020. (Accessed on 25.11.2022)

Kongsberg to develop a new generation of unmanned IFVs.[802] The pivotal role of Milrem in Europe was further heightened by the signature of a minority share of Krauss-Maffei Wegmann into the Estonian company by 24.9% in 2021.[803] Estonia's UGVs market is projected to reach USD 14 million in 2025, up from 6 million in 2022.

Estonia has not invested significantly in UMS, as its very small navy of 4 ships is focused solely on coastguard and mine countermeasures, and it relies almost entirely on NATO partners for patrolling the Baltic Sea.[804] Yet, thanks to PESCO's M-SAVS project, Estonia collaborates closely with several European partners to develop the medium-sized USV of the future (see Table 9). Estonia's UMSs market is forecasted to grow from USD 3 million in 2022 to 11 million by 2025.

[802] Milrem Robotics and Kongsberg to develop Nordic Robotic Wingman RCV, *Army Technology,* https://www.army-technology.com/news/milrem-kongsberg-develop-nordic-robotic-wingman/, 15 September 2021. (Accessed on 25.11.2022)
[803] Krauss-Maffei Wegmann acquires stake in Milrem Robotics, *MILREM Robotics*, https://milremrobotics.com/krauss-maffei-wegmann-acquires-stake-in-milrem-robotics/, 31 May 2021. (Accessed on 14.10.2022)
[804] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS)*, 2022.: 100.

Figure 32 - Retrospective table of ten European countries' developments in military robotics.[805]

	Impact of the 4 main factors driving innovation[806]	*Defence-related innovation organisation & governance*	*Supra-national development projects (non-exhaustive)*	*Doctrine development on military robotics*	*Size of military robotics market (in USD million)*
UK	Strong	Complete & effective High funding Collaboration private-public sectors	NATO, AUKUS US, FR, GER, NED, NOR, SWE, ITA-JAP	Advanced (all levels: strategic, operational and tactical)	2019: = 205 2025: = 595 CAGR = 20.1%
FRA	Strong	Centralised & effective High funding Good integration of all innovation actors	NATO, EU (PESCO, HEDI, EDA, EDIDP) US, CAN, NED, SIN, UK, GER, EGY, IND	Advanced (especially at the tactical level)	2019: =150 2025: = 455 CAGR = 20.6%
GER	Weak	Decentralised & relatively ineffective High funding " Firewall"	NATO, EU (all) US, FR, SPA	Intermediate, contradicting documents	2019: = 172 2025: = 606 CAGR = 23.4%
ITA	Intermediate	Ongoing reform on R&D Intermediate funding Academia absent	NATO, EU (all) US, GRE, ARM, ISR JAP-UK, QAT, IND	Advanced (multiple docs) Integration with AI and other EDTs	2019: = 113 2025: =354 CAGR = 22%
SPA	Intermediate	Decentralised & relatively ineffective Intermediate funding SMEs vs. big groups	NATO, EU (all) US, UK, FR-GER, GRE, MOR, ISR	Intermediate AI military strategy unclear about military robotics	2022: = 232 2025: = 425 CAGR = 22.4%
NED	Intermediate	Decentralised Intermediate funding Inclusive open innovation scheme	NATO, EU (all) US, FR, GER, UK, BEL, EST, ROC	Intermediate AI military strategy in development	2022: = 162 2025: = 294 CAGR = 22%
POL	Very strong	Centralised & relatively ineffective Intermediate funding Too state-centred	NATO, EU (all) US, SWE, TUR, SK, UKR, LIT	Intermediate Focus on traditional conventional capabilities	2022: = 139 2025: = 251 CAGR = 22.4%
NOR	Strong	Trio-system, effective High funding & effective Integration private actors	NATO, agreement with EDA, NORDEFCO US, UK, NED, UKR, ISR,	Advanced (all levels: strategic, operational, and tactical)	2022: = 74 2025: = 163 CAGR = 31%
SWE	Strong	Trio-system, effective High funding Effective div. of labour	EU (all), NORDEFCO, (NATO soon) US, UK, FIN, FR, POL	Rrelatively basic No AI or EDTs military strategy	2022: = 73 2025: = 133 CAGR = 22.3%
EST	Very strong	Centralised & effective Niche-oriented High funding despite size	NATO, EU US, UK, GER, FR, CAN, UKR, SPA, TUR	Intermediate Advanced on AI, unclear about military robotics	2022: = 46 2025: = 90 CAGR = 25.1%

805 Figure made by the authors.

806 The four indicators are the following: 1) geopolitical environment and threat perception; 2) convergence in political, military and societal support for defence-related innovation; 3) innovation organisation and governance; and 4) investment in defence-related innovation. An explanation and justification of the relevance of these factors can be found on page 77.

Chapter 4: Switzerland and military robotic systems, a comparative analysis

Switzerland is currently at a crossroads in terms of foreign and security policy. Indeed, the first drivers of defence innovation, namely: (1) the geopolitical environment and threat perceptions and, (2) political, military and societal support for defence innovation, are both evolving at a rapid pace resulting from Russia's attack on Ukraine in February 2022. While it is still too early to fully grasp the implications of what political scientist Richard Haas has called the "Return of History", it is nonetheless imperative for Switzerland to adapt its foreign, security and defence policies accordingly to respond to the changing nature of the upcoming historical era.[807] Moreover, the relative destabilisation of the international order triggered by the war in Ukraine also highlights older trends in Switzerland's strategic posture, which are rooted in the following: (3) a progressive reform of the governance architecture of military-related innovation and, (4) increased investment in defence-related innovation.

The aim of this chapter is to define Switzerland's capacity to develop defence-related innovations and, especially, military robotic systems. As in the previous case studies, the four main innovation factors are analysed here to provide a comprehensive picture of the situation. First, this chapter highlights the evolution of Switzerland's external environment since 1991 to illustrate how the Swiss Confederation has responded and revised its policy, posture, and strategy. Next, threat perceptions in Bern and general support for defence-related issues are highlighted to show the extent to which the first and second factors play a role. It then examines Switzerland's defence-related innovation base to better understand how it functions and how it relates to the military domain, and to shed light on the impact of the third identified innovation factor. The doctrine of the Swiss armed forces is then examined, to show its developments – or lack thereof – and to see how the military intends to integrate robotic systems. Finally, Switzerland's investments and markets in military robotics are explored to provide a picture of the relevance of this field to the country. This quantifies the fourth factor driving defence-related innovation.

The heuristic value of this chapter is based not only on the specific case of Switzerland, but also on a comparative analysis with the other countries mentioned above. Thus, by detailing the characteristics of the Swiss case and linking it to other countries, the study illustrates how Switzerland compares with other European countries of different size, wealth, technological advancements and political priorities. Understanding how other countries perceive and respond to their security environment, how they organise their institutions to foster defence innovation, how they integrate military robotic systems into their armed forces, and how much money they invest in these systems is of major relevance in defining trends and implications from a Swiss perspective. This critical analysis, when applied to Switzerland in comparison to the other countries, is the necessary step to reflect on how Switzerland can and should deal with the new challenges posed by military robotics. In addition, this chapter provides an empirical ground for the policy recommendations in Chapter 5.

[807] Haas, Richard. Ten Lessons from the Return of History, *Project Syndicate*, https://www.project-syndicate.org/commentary/ten-international-relations-lessons-of-2022-by-richard-haass-2022-12?barrier=accesspaylog, 13 December 2022. (Accessed on 08.02.2023)

Switzerland's geopolitical environment in turmoil

From Simferopol to Kyiv: the return of history

In late February 2014, military personnel without insignia, later dubbed "little green men", took control over Crimea's regional capital, Simferopol, and handed power to pro-Russian separatists.[808] It soon became clear that the Kremlin's hand was behind this illegal action when, on March 18, President Putin ratified the treaty annexing Crimea after a referendum.[809] For Switzerland, the Crimean crisis and its aftermath posed a strategic challenge: on the one hand, Russia's revisionism had to be condemned as a matter of principles and international credibility; on the other hand, Switzerland maintained excellent political relations with Russia at the time and did not want to undo years of diplomatic efforts overnight.[810] To complicate matters further, Switzerland held the rolling chairmanship of the OSCE in 2014, which further forced Bern to seek a mediating role.[811] Ultimately, Bern decided not to impose any major sanctions on Russia, other than targeting only two dozen individuals close to Putin and expressing concerns about Moscow's behaviour.[812] This decision had a negative impact on Switzerland's relations with European countries, especially the Baltic and Eastern states.[813]

The Crimean crisis opened the eyes of much of the Swiss population and policymakers to the reality of geopolitics, confirming what one close observer described in blunt terms: "the Jungle grows back."[814] As the 2016 report of the Swiss Federal Intelligence Service put it: *"A 25-year-long era in which inter-state conflicts on the 'old continent' were on the decline has come to an end. A return to a situation like the one which has prevailed over the last two decades, in which movement toward the goal of a common security area from the Atlantic to the Urals was at least a long-term prospect, has now become unlikely."*[815] In a sense, the Crimean crisis was a prologue to many more disruptive global events and trends, including the arrival of Donald Trump in the White House in early 2017, the destabilisation of NATO, and the growing rivalry between the US and China.[816] Add to this the ongoing nuclear proliferation programmes of Iran and North Korea, Russia's support for Syrian dictator Al-Assad, China's growing military pressure on Taiwan, and the turmoil caused by the COVID-19 pandemic, which exposed the limits of multilateral governance, and a bleak picture of the international order emerges.

In response to these challenges, Bern's diplomacy has focused on strengthening multilateralism, even though most arenas of international governance have been weakened by increasing regional and global competition. This was reflected in particular in an increased commitment to the OSCE and a bid to join the UN Security Council as a non-permanent

[808] Kofman, Michael, et al. "Lessons from Russia's Operations in Crimea and Eastern Ukraine". Research Report, *RAND Corporation*, 2017.: 7.
[809] Putin reveals secrets of Russia's Crimea takeover plot, *BBC News*, https://www.bbc.com/news/world-europe-31796226, 9 March 2015. (Accessed on 13.02.2023)
[810] Foulkes, Imogen. Swiss sanctions dilemma over Russia, *BBC News*, https://www.bbc.com/news/business-28833360, 19 August 2014. (Accessed on 10.02.2023)
[811] Burnand, Frédéric. Swiss walk tightrope between the West and Russia, *swissinfo*, https://www.swissinfo.ch/eng/crimea-annexation_swiss-walk-tightrope-between-the-west-and-russia/38164078, 16 March 2014. (Accessed on 13.02.2023)
[812] Situation in Ukraine: Federal Council decides on further measures to prevent the circumvention of international sanctions, *Swiss Confederation*, https://web.archive.org/web/20140908113316/https://www.news.admin.ch/message/index.html?lang=en&msg-id=54221, 27 August 2024. (Accessed on 17.02.2023)
[813] Russia says Swiss steps 'counterproductive', *swissinfo.ch*, https://www.swissinfo.ch/eng/crimea-reaction_russia-says-swiss-steps--counterproductive-/38266402, 28 March 2014. (Accessed on 16.08.2023)
[814] Kagan, Robert. *The Jungle Grows Back: America and Our Imperiled World*. First Vintage Books edition. New York: Vintage Books, a Division of Penguin Random House LLC, 2019.
[815] Switzerland's Security, Situation Report 2016 of the Federal Intelligence Service, *FIS*, 2016.: 16.
[816] Elfer, Helen. Trump was planning to withdraw US from Nato and ditch South Korea alliance, according to new book, *The Independent*, https://www.independent.co.uk/news/world/americas/us-politics/trump-nato-south-korea-book-b1883457.html, 13 July 2021. (Accessed on 13.02.2023)

member for the 2023-24 cycle.[817] At the same time, the Swiss armed forces adopted the "DEVA" concept, a reform that aimed at increasing its readiness – allowing up to 35'000 soldiers to be mobilised in 10 days if necessary – and modernising and renewing its equipment.[818] Although the Swiss armed forces have undergone a number of reforms, the small budget (still substantially less than 1% of GDP since 2001) has remained problematic for capability development.[819] Switzerland's relationship with NATO also suffered from Bern's passivity and from the Alliance's re-focusing on collective defence and deterrence to counter Russia's renewed aggressiveness. In this context, Switzerland had little to offer to NATO and, despite some participations of the Swiss armed forces in NATO exercises – such as in "Arctic Challenge 2017" and "Trident Juncture 2018" – the priorities of the two actors diverged more and more during the period 2014-2022.[820]

The Crimean crisis opened the eyes of much of the Swiss population and policymakers to the reality of geopolitics, confirming what one observer depicted in blunt terms: "the Jungle grows back."

If 2014 was a rude awakening, 2022 represented nothing less than a year of upheaval. Russia's invasion of Ukraine took most policymakers in Bern by surprise, despite numerous warnings from US intelligence agencies that the Kremlin was not bluffing.[821] As evidence, at the end of 2021, the Swiss Federal Intelligence Service (FIS) still considered that the risk of a major conventional war in Europe to be relatively low (2 out of 6): *"The ceasefire in eastern Ukraine is likely to be broken frequently but not officially terminated."*[822] While Bern initially appeared to be playing for time, waiting to see how its partners' would react, Ukraine's resistance, combined with Russian military counter-performances, convinced most Western states to take sides and to collectively sanction the Kremlin.[823] Switzerland followed the EU in adopting its sanctions point by point, while declaring that the position was in line with its unchanged policy of neutrality.[824] Bern's response to this crisis was a significant change in Swiss foreign policy, described in the foreign medias as a "major shift" or "a break with tradition".[825] This new concept of neutrality was described in a document published by Foraus as "cooperative neutrality", based on moral values and solidarity, and intended to free Switzerland from isolation and passivity in the face of the growing polarisation of the international system.[826]

817 Switzerland on the UN Security Council, *Federal Department of Foreign Affairs (FDFA)*, https://www.eda.admin.ch/eda/en/fdfa/foreign-policy/international-organizations/un/switzerland-commitment/UNO-Sicherheitsrat.html. (Accessed on 13.02.2023)

818 Développement de l'armée (DEVA) : L'Armée Suisse d'aujourd'hui, *Armée Suisse*, 2018.: 6.

819 Poll: most Swiss are reluctant to increase defence spending, *swissinfo*, https://www.swissinfo.ch/eng/politics/poll--most-swiss-are-reluctant-to-increase-defence-spending/47450238, 21 March 2022. (Accessed on 15.02.2023)

820 Larsen, Henrik. "Die Schweiz und die NATO: neue Konvergenz." *Center for Security Studies (CSS*), ETH Zurich, 11 December 2019.: 69.

821 US intelligence believes Russia has ordered Ukraine invasion – reports, *The Guardian*, https://www.theguardian.com/us-news/2022/feb/20/russia-invasion-ukraine-biden-blinken-us-national-security-council, 20 February 2022. (Accessed on 13.02.2023)

822 Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS*, 2021.: 14.; 29.

823 Marson, James. The Ragtag Army That Won the Battle of Kyiv and Saved Ukraine, *Wall Street Journal*, https://www.wsj.com/articles/russian-invasion-ukraine-battle-of-kyiv-ragtag-army-11663683336, 20 September 2023. (Accessed on 15.02.2023)

824 Clarté et orientation de la politique de neutralité, Rapport du Conseil fédéral, *Confédération Suisse*, 2022.: 19.

825 Jones, Sam. Swiss break neutrality tradition to match EU sanctions on Russia, *Financial Times,* https://www.ft.com/content/80c268fa-61d4-42ac-a9f4-310f12678c43, 28 February 2023. (Accessed on 15.02.2023)

826 Jauslin, Karl et al. "Kooperative Neutralität Sieben Empfehlungen für ein Update der Schweizer Neutralität", *Foraus Policy Brief, Programm Diplomatie & internationale Akteure*, 2022.: 52.

The shock of a large-scale conventional war in Europe has forcefully revived the national debate on Switzerland's place in the European security architecture, and on the strategic position that Bern should adopt in the foreseeable future. At the heart of this debate is the evolution of the Swiss security conception. Traditionally, *"(…) when the Swiss thought of their security what they had in mind was the security of their own small country."*[827] For most Swiss, this almost mythological importance of territorial defence goes back to the parts of national history they learned at school, such as when the three Confederate states of Uri, Schwytz and Unterwald defeated the Habsburg emperor Leopold I at Morgarten (1315). This idea of territorial defence, which is deeply rooted in the minds of Swiss citizens prevents an intellectual revision of the Swiss defence concept.

However, Russia's aggression against Ukraine seems to have convinced many Swiss people that their country should take responsibility for the security of Europe. Stephan Holenstein, former President of the Swiss Officers' Society (Schweizerischen Offiziersgesellschaft, SOG) expressed this view forcefully in an interview: *"Now we finally realise that security is the basis for everything: for freedom, democracy, our federal constitutional state, democracy, our armed neutrality."*[828] Not only the elites, but also a significant part of the Swiss population has changed its perspective on security and defence policy in the light of Russia's blatant violation of international norms: in a survey conducted by CSS and the ETH's Military Academy (Militärakademie an der ETH Zürich, MILAK), 80% of respondents believed that the Swiss armed forces were necessary to ensure the country's prosperity, a result that was 21% higher than in 2001.[829] Similarly, this survey suggests that the Swiss population recognises that Switzerland needs to play a more active role in conflicts, with 78% of respondents agreeing in 2022, up from 66% in 2011.[830] In addition, 52% respondents believed that Switzerland should work more closely with NATO, an increase of almost 20 percent from 33% in 2003.[831] More and more Swiss citizens believed that Switzerland should seek closer cooperation with other states to ensure its security, with 33% in 2022 compared to 25% in 1999.[832] Importantly for the issue of capability development, 70% of respondents believed that it is necessary to maintain a well-equipped army, up from 60% in 2017.[833]

This important current within the Swiss political establishment and the population was well summed up in an NZZ article titled *"The end of hedgehog Switzerland: cooperation with NATO must be massively strengthened"*.[834] This piece highlights the obsolescence of Switzerland's "hedgehog strategy", which consists of curling up and sticking out its spine out when directly threatened, but remaining passive when others are attacked. Indeed, Switzerland's post-Cold War security and defence policies were largely based the idea of "the end of history" according to which wars were a relic of the past and the conviction that Switzerland would be able to defend its territorial integrity militarily by its own means. Both assumptions have been largely challenged in 2022, and *"the current power-political constellation clearly shows that the principle of autonomous defence capability no longer applies absolutely in a modern conflict.*

[827] De Gruyter, Caroline. Switzerland Flirts With NATO, *Foreign Policy,* https://foreignpolicy.com/2022/05/05/switzerland-nato-cooperation-russia-ukraine-war-neutrality/, 5 May 2022. (Accessed on 16.02.2023)
[828] Novak, Eva. Die Schweiz und die Nato: «Flirten ja, heiraten nein», *furrerhugi*, https://www.furrerhugi.ch/de-ch/influence/2022/die-schweiz-und-die-nato-%C2%ABflirten-ja,-heiraten-nein%C2%BB, 25 March 2023. (Accessed on 16.02.2023). Translation by the authors.
[829] Tresch, Tibor Szvircsev et al. "Nachbefragung der Studie «Sicherheit 2022» aufgrund des Krieges in der Ukraine Aussen-, Sicherheits- und Verteidigungspolitische Meinungsbildung im Trend", *Militärakademie (MILAK), Center for Security Studies (CSS)*, ETH Zürich, 2022.: 42.
[830] *Ibid.:* 20.
[831] *Ibid.:* 24.
[832] *Ibid.:* 28.
[833] *Ibid.:* 185.
[834] Burkhart, Thierry. Das Ende der Igel-Schweiz: Die Zusammenarbeit mit der Nato muss massiv verstärkt warden, *Neue Zürcher Zeitung (NZZ),* https://www.nzz.ch/meinung/das-ende-der-igel-schweiz-die-zusammenarbeit-mit-der-nato-muss-massiv-verstaerkt-werden-ld.16782568, April 2022. (Accessed on 16.02.2023). Translation by the authors.

Neither from a technological nor from a financial point of view can a self-reliant defence be guaranteed today."[835] For more than three decades, this paradigm has led Swiss security and defence policy to a problematic point: Bern has benefited from the "peace dividend" and its geographical location at the heart of Europe but has been politically reluctant to commit itself further to the European security architecture. This position is increasingly being criticised outside of Switzerland: *"(…) Russia' invasion of Ukraine, and Switzerland continued insistence on not getting involved in a war that threatens all of Europe, has irritated Western countries that had previously accepted its claims of neutrality. There is growing criticism in Western capitals at just how easy Bern has had it all these years."*[836] In this respect, 2022 is a turning point for Switzerland, laying the groundwork for an overhaul of its foreign, security and defence policies.[837]

The view from Bern: Switzerland's threats perception

As the Future Conception of the Armed Forces 2022 (*Conception Avenir de l'Armée*) states: *"(…) something broke out on 24 February: the belief that the borders between European states and their territorial integrity are intangible, that inter-state conflicts can be resolved peacefully and that the use of military force or the threat of it should never be a solution has been shattered."*[838] The events of 2022 are likely to have major and long-lasting consequences for Switzerland. From Bern's perspective, the future is uncertain and geopolitical threats can be divided into three categories: (1) foreign security policy, with the overwhelming importance of the Russian military threat to Europe and the dangers posed by the continuation of high-intensity conventional warfare, (2) cybersecurity and proliferation and, (3) jihadist terrorism and other forms of extremism. The FIS Swiss Security Report 2022 illustrates the major threats facing Switzerland.[839] The 2023 Report picks up on these elements, describing the current international context as volatile, unpredictable, and uncertain.[840]

The first threat (1) is the risk of a conventional conflict between Russia and NATO, which, according to the report, has risen from level 2 in 2021, to level 6 out of 6 in 2022 with the large-scale Russian invasion of Ukraine. Threat (1) is by far, the most significant risk to Switzerland's security, while threats (2) and (3) are of a much lesser magnitude. Firstly, the Russo-Ukrainian war is a major event in Europe because it has triggered new geopolitical dynamics, with a noticeable weakening of the influence of the Franco-German leadership on geopolitical issues, and the subsequent emergence of eastern states such as Poland, the Czech Republic and the Baltic States, but also Sweden and Finland, as drivers of Europe's security policy. In this regard, Europe's strategic centre has gradually shifted eastwards since February 2022, mainly because these states have proven to be much more responsive and willing to respond to Russia's aggression.[841] Therefore, after years of political directions largely shaped by Berlin and Paris, especially in the aftermath of 2007-2008 sovereign debt crisis and the COVID pandemic, the Ukraine war brings forth a new paradigm: *"It also means that Franco-German plans to uphold a clear distinction between countries in or out of institutions such as the*

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[835] *Ibid.*
[836] Vohra, Anchal. Swiss Neutrality Makes No Sense Anymore. *Foreign Policy*, https://foreignpolicy.com/2023/03/24/switzerland-neutrality-russia-ukraine/?tpcc=recirc_latest062921, 24 March 2023. (Accessed on 27.03.2023)
[837] Clarté et orientation de la politique de neutralité, Rapport du Conseil fédéral, *Confédération Suisse*, 2022.; Alimentierung von Armee und Zivilschutz Teil 2: Möglichkeiten zur langfristigen Weiterentwicklung des Dienstpflichtsystems, Schweizerische Eidgenossenschaft, *Eidgenössisches Department für Verteidgung, Bevölkerungsschutz und Sport (VBS),* 2022.: 7.
[838] Conception – Avenir de l'Armée, Département fédéral de la Défense, de la Protection de la population et des Sports (DDPS), *Armée Suisse*, 2022.: 3. Translation by the authors.
[839] Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS*, 2022.: 15.
[840] Sicherheit Schweiz, Schweizerische Eidgenossenschaft, *Nachrichtdiest des Bundes*, 2023.: 26.
[841] Coughlin, Con. Poland is now the true leader of free Europe, *The Telegraph,* https://www.telegraph.co.uk/news/2022/04/28/poland-now-true-leader-free-europe/, 28 April 2022. (Accessed on 17.02.2023)

European Union and Nato must be abandoned.'[842] In this context, the US will remain the primary actor in European security for some time to come, especially if a Democrat administration remains in the White House in 2024. Additionally, many European countries will adopt reformed defence postures, with some doubling down on large-scale conscription such as Denmark, and others largely revising their policy, such as Italy or Germany with its *Zeitenwende*.[843] These are realities that Switzerland will have to take into account: *"Security policy in general and the role of defence in particular are once again gaining in importance, after having been overshadowed by other policy areas in recent decades, particularly in Europe."*[844]

The Russia-Ukraine war is not only significant on a European scale, it also has major geopolitical repercussions, in particular on the strategic competition that is structuring our era, between China and the USA.[845] Generally speaking, Switzerland is concerned about the possible emergence of a world divided into two blocs, one composed of liberal democracies committed to maintaining the current world order led by the United States, and the other composed of authoritarian and revisionist states collaborating in destructuring the world system, headed by China, Russia and Iran.[846] There is undoubtedly a growing body of evidence to support this thesis of two increasingly antagonistic blocs, even if this theoretical prism may be misleading with regard to the position of certain important countries such as India or Brazil. In parallel, convergence between the EU and the US in the context of growing threats has been highlighted in the EU *Strategic Compass* and represents an important milestone for further cooperation between these two actors.[847]

The intensification of the strategic partnership between China and Russia, the material support provided by Iran and North Korea for Moscow's war efforts are all symbols of the rise of an authoritarian front. In such an international context, Switzerland's role as a mediator will be both more difficult and more necessary. More difficult, because, as mentioned above, it is increasingly in Switzerland's interest to profile itself as an actor offering fruitful "bons offices", but more difficult, because in a polarised system, the pressure to choose sides becomes more intense.[848] The early Cold War is a perfect example of how critical geopolitical competition between antagonistic powers can affect Switzerland's international position: The informal Hotz-Linder Agreement of 1951 was the result of Washington's intense pressure on Bern to force Switzerland to stop trading "strategic goods" with members of the Warsaw Pact, therefore endangering neutrality.[849] Bern is also concerned by the possibility of commercial and industrial decoupling between the US, Europe and China, which would jeopardise the Swiss economy, which is based on the export of high-quality services and products.[850]

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842 Eyal, Jonathan. Amid the smoke of war, power in Europe is shifting decisively to the east, *The Guardian*, https://www.theguardian.com/commentisfree/2023/jan/29/amid-the-smoke-of-war-power-in-europe-is-shifting-decisively-to-the-east, 29 January 2023. (Accessed on 18.02.2023)
843 Gady, Fran-Setfan. For Europe, Military Conscription Is No Answer to Russia's War, *Foreign Policy*, https://foreignpolicy.com/2023/02/14/europe-nato-military-russia-war-ukraine-conscription-draft-reserves-training-manpower/, 14 February 2023. (Accessed on 18.02.2023)
844 Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS*, 2022.: 21.
845 Feigenbaum, Evan A. and Szubin, Adam. What China Has Learned from the Ukraine War, *Foreign Affairs*, https://www.foreignaffairs.com/china/what-china-has-learned-ukraine-war, 14 February 2023. (Accessed on 17.02.2023)
846 Legvold, Robert. "Two Cold Wars and a New Bipolar World". *The National Interest*, 2022.
847 A Strategic Compass for Security and Defence, European Union, *European External Action Service (EEAS)*, 2022.: 56.
848 Switzerland in the world 2028, Report by the working group 'Switzerland's 2028 Foreign Policy Vision', *Federal Department of Foreign Affairs (FDFA)*, 2019.: 32.
849 Spillmann, Kurt R.,et al. *Schweizer Sicherheitspolitik seit 1945: zwischen Autonomie und Kooperation*. Zürich: Verlag Neue Zürcher Zeitung (NZZ), 2001.: 45.
850 Kucik, Jeffrey and Menon, Raja. Can the United States Really Decouple From China?, *Foreign Policy*, https://foreignpolicy.com/2022/01/11/us-china-economic-decoupling-trump-biden/, 11 January 2022. (Accessed on 17.02.2023)

According to the second threat cluster (2), cybersecurity remains a critical topic, particularly in the context of Russia's attack on Ukraine. Indeed, asymmetric means of warfare are an essential element of Russian military doctrine in the NGW, and Switzerland has already been the target of Russian cyberattacks in the past.[851] Attacking critical infrastructure such as transport networks and energy facilities with non-kinetic means, targeting governments services, and disrupting key services such as banking and access to information are all methods that Russia has used to undermine Ukraine, and could be used against Switzerland.[852]

Generally speaking, Switzerland is concerned about the possible emergence of a world divided into two blocs, one composed of liberal democracies committed to maintain the current world order led by the United States; the other composed of authoritarian and revisionist states collaborating in destructuring the world system, headed by China, Russia and Iran.

In addition, the proliferation of nuclear weapons and WMD is considered as an increasing threat for Switzerland, as 2022 has recorded President Putin's repeated nuclear threats but also the development of China's nuclear arsenal.[853] The relative stalemate over the JCPOA, the further deterioration of US-Iranian relations amid Tehran's transfer of attack drones to Russia do not bode well for the prospect of keeping Iran out of reach of the ultimate weapon.[854] North Korea conducted more than 90 missile-tests in 2022, more than in any previous year, and is believed to have reached the full range of capabilities, including Intercontinental Ballistic Missiles (ICBMs) with its Hwasong-17.[855] In response to these events, South Korea and Japan are currently considering the possibility of acquiring nuclear weapons, further weakening the strategic arms control regime.[856] In addition to this alarming increase in nuclear proliferation, *"(…) arms control has been one of the victims of Russia's war of aggression against Ukraine."*[857] Indeed, the US-Russia verification regime has been virtually abandoned and trust between the two states is at an all-time low. President Putin withdrew from the New START Treaty in February 2023.[858] In such a context, Switzerland has few options other than to advocate for the value of the Non-Proliferation Treaty (NPT), the Comprehensive Nuclear-Test-Ban Treaty (CNTBT) and ratifying the Treaty on the Prohibition of Nuclear Weapons (TPNW).[859]

[851] De Gruyter, Caroline. Switzerland Flirts With NATO, *Foreign Policy,* https://foreignpolicy.com/2022/05/05/switzerland-nato-cooperation-russia-ukraine-war-neutrality/, 5 May 2022. (Accessed on 16.02.2023)
[852] Switzerland's Security 2021, Situation Report of the Federal Intelligence Service*, FIS,* 2022.: 72.
[853] Missile Defense Project, "Missiles of China", *Center for Strategic and International Studies (CSIS),* 12 April 2021, https://missilethreat.csis.org/country/china/. (Accessed on 18.02.2023)
[854] Nelson, Steven. Joe Biden blurts out Iran nuclear deal 'dead' — but he can't 'announce' it, *New York Post*, https://nypost.com/2022/12/20/biden-iran-nuclear-deal-is-dead-but-we-are-not-going-to-announce-it-long-story/, 20 December 2022. (Accessed on 18.02.2023)
[855] Dotto, Carlotta et al. North Korea's record year of missile testing is putting the world on edge, *CNN*, https://edition.cnn.com/2022/12/26/asia/north-korea-missile-testing-year-end-intl-hnk/index.html, 26 December 2022. (Accessed on 17.02.2023)
[856] Sang-Hun, Choe. In a First, South Korea Declares Nuclear Weapons a Policy Option, *New York Times*, https://www.nytimes.com/2023/01/12/world/asia/south-korea-nuclear-weapons.html, 12 January 2023. (Accessed on 18.02.2023)
[857] Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS*, 2022.: 60.
[858] Mackinnon, Amy. Putin's New START Announcement and the Future of Arms Control, *Foreign Policy*, https://foreignpolicy.com/2023/02/21/putin-new-start-announcement-arms-control-nuclear-weapons-united-states-war/, 21 February 2023. (Accessed on 22.02.2023)
[859] Rapport du groupe de travail sur l'analyse du Traité sur l'interdiction des armes nucléaires, *Département Fédéral des Affaires Etrangères (DFAE)*, 2018.: 3.

Threats / Consequences	1.Conventional conflict In Europe	2.Cybersecurity / Proliferation of WMD	3.Religious and political extremism
Risk assessment as of 2022	**6/6**	**4.5/6**	**4/6**
Main consequences	Russia-NATO confrontation as the structuring element of Europe's security GER-FR duo less of a driving force, trumped by eastern countries such as the Balts and Poland Increasing competition between authoritarian states / democracies	Cyberwarfare as asymmetric threats for CH Russia's threats of nuclear use in Europe are concerning for CH Iran & North Korea are increasingly menacing	Jihadism remains an important threat to national security Spread of conspiracy theories, anti-vax, pro-Russian narratives, and fake news are a great societal challenge
Important developments for Switzerland	Polarising geopolitical landscape = neutrality more difficult Open/free economic exchanges more difficult	Unravelling of strategic & arms control framework is bad news More countries will seek nuclear or WMD as security guarantee	Strengthening of transnational networks of terrorism Asymmetric threats are sometimes supported by states (ISIS, pro-Russian extreme right, etc.)

Figure 33 - Summary of Switzerland's threat perception as of 2022.[860]

The third group of threats (3) is political extremism, mainly jihadist, left-wing and right-wing. This topic has somehow fallen down the list of priorities. Although Europe has not suffered any attacks by ISIS or al-Qaeda since November 2020, it is estimated that these actors have strengthened their organisations on Swiss territory in recent years.[861] As a result, the threat remains acute, and *"although the Islamist movement in Switzerland is still disparate in nature and largely uncoordinated, it could in the long run pose a threat to the security of Switzerland."*[862] Violent extremism from left- and right-wing groups is also an issue, especially after years of spreading conspiracy theories supported by anti-vax and pro-Russian movements across Europe.[863] These groups have become more violent and aggressive towards federal authorities, and they are increasingly linked to transnational organisations.

[860] Figure made by the authors. *Source*: Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS,* 2022.: 15.
[861] Germany, Switzerland arrest suspected ISIS sympathizers, *Alarabiya News,* https://english.alarabiya.net/News/world/2022/06/14/Germany-Switzerland-arrest-suspected-ISIS-sympathizers, 24 June 2022. (Accessed on 17.02.2023)
[862] Switzerland's Security 2021, Situation Report of the Federal Intelligence Service, *FIS*, 2022.: 44.
[863] Eberhard, Fabian. Qui sont ces néonazis suisses qui participent aux manifestations antimesures Covid?, *Blick*, https://www.blick.ch/fr/news/suisse/on-a-besoin-de-vous-qui-sont-ces-neonazis-suisses-qui-participent-aux-manifestations-antimesures-covid-id17190319.html, 20 January 2022. (Accessed on 18.02.2023)

In summary, the first two drivers of defence innovation, namely (1) the geopolitical environment and threat perception and (2) the political, military and societal support for defence innovation, are increasingly strong in Switzerland. The dissolution of Europe's traditional security architecture following Russia's invasion of Ukraine, the Swiss population's support for a more active role in the international arena and active defence and security policies, and Bern's threat perception all point to the need for Switzerland to rethink the country's strategic and military posture. The first two innovation factors provide a strong incentive for Switzerland to invest more in defence innovation. The next section looks at how Switzerland invests in defence-related innovation, how the Swiss defence innovation system is organised, and how this affects Switzerland's overall defence innovation. Figure 33 summarises Switzerland's threat perception.

Compared to other countries, Switzerland has an excellent network of government-supported, industry-related academic institutions.

Defence-related innovation and governance

Switzerland defence spending and innovation investments

Switzerland currently spends around 0.7% of its GDP on defence, which will amount to USD 5.72 billion (CHF 5.2 billion) in 2022.[864] The events of 2022 are expected to have a significant impact on the military budget, as the Federal Council has decided to raise defence spending above 1% of GDP, with an announced investment of USD 23.1 billion (CHF 21.7 billion) for the period 2021-2024, and an annual defence budget of around USD 8 billion (CHF 7.37 billion) by 2030.[865] If realised, this would break with more than 20 years of defence spending below 1% of GDP, but would still be relatively low compared to the 3% that Switzerland spent during the Cold War (FY 1958).[866] This increase in defence budget would still mean that Switzerland is behind countries such as the Netherlands (1.4% of GDP in 2020) and France (2.1%), but it is an important development. Another relevant measure for understanding Switzerland's defence spending is per capita spending, or more simply, the amount of money the government invests in defence divided by the total population of the country. This measure gives an idea of the intensity of a state's defence expenditure and allows for a more detailed international comparison. With a per capita defence expenditure of USD 658.8 in 2020, Switzerland is among the top 20 countries in the world. This places Switzerland between Sweden (639) and the Netherlands (734.1), ahead Germany (629.8) and Estonia (528.5).[867] This means that despite spending a smaller proportion of GDP on defence, the fact that the Swiss economy is one of the five strongest in the world per capita allows Bern to spend more intensively than larger European states.[868]

[864] Hackett, James. *The Military Balance. 2022*. Abingdon, Oxon, London: Routledge; *The International Institute for Strategic Studies (IISS),* 2022.: 153. For this chapter, USD and CHF are used as reference currencies. For heuristic reasons, this study usually uses the following exchange rate: CHF 1 = USD 1.1.
[865] Message sur l'Armée 2023, Armée Suisse, *Département de la Défense, de la Protection de la population et des Sports (DDPS)*, 2023.: 4-5.
[866] SIPRI Military Expenditure Database, *SIPRI*, https://milex.sipri.org/sipri. (Accessed on 08.03.2023)
[867] *Ibid.*
[868] Swiss Economy – Facts and Figures, *Discover Switzerland*, https://www.eda.admin.ch/aboutswitzerland/en/home/wirtschaft/uebersicht/wirtschaft---fakten-und-zahlen.html (Accessed on 08.03.2023)

Switzerland is one of the most advanced countries in the world in terms of R&D and innovation. Over the past decade, it has consistently ranked first in the Global Innovation Index, the Global Talent Index and the Global Competitiveness Ranking.[869] Switzerland also has two institutions – ETH Zurich and EPF Lausanne – among the world's top 20 universities for engineering and science.[870] In addition, *"(…) numerous independent, federally funded research institutions help to bring added value to research."*[871] In the defence sector, Switzerland spent USD 109 million (CHF & EUR 103 million) on R&D in 2019, as shown in Figure 17. This figure only includes applications of a purely defence-related nature and does not cover dual-use technologies. Thus, with EUR 103 million of defence R&D investment, Switzerland ranks behind the major European powers such as France (1.3 billion), the UK (1.25 billion) and Spain (128.1 million) but ahead of players such as Norway (85 million), Sweden (90.6 million) and even the Netherlands (87.9 million). In terms of defence R&D expenditure, Switzerland is thus at the upper end of the so-called "middle powers", behind the largest European states but ahead of smaller and medium-sized players such as Estonia and Sweden. It is important to note that defence-related R&D in Switzerland has increased significantly, with an annual growth rate of 14.5% over the period 2017-2019, from EUR 79 million in 2017 to EUR 103 million on R&D in 2019.[872] This is in line with Switzerland's intensive investment in R&D activities in general, with 3.15% of its GDP, ranking just behind Israel, South Korea, Sweden and Germany.[873]

Switzerland has 16 ATITCs, of which 2 are mainly focused on drones and 9 on robotics (Figure 18). The main research centres in the field of drones and robotics are the Autonomous Systems Lab (ASL) at ETHZ, the Laboratory of Intelligent Systems (LIS) at EPFL, and the National Centre of Competence in Research (NCCR).[874] The ASL has produced important spin-off companies over the past two decades, such as AtlantikSolar and Auterion, two companies producing small fixed-wings and VTOL UAVs. The LIS has produced widely recognised drone companies such as Sensefly and Flyability were founded.[875] The NCCR is a network funded by the Swiss National Research Fund (SNRF) that aims to bring together leading experts from all Switzerland's ATITCs, academic institutions and industry to support start-ups and create spin-offs in the field of robotics.[876]

The Swiss Drones and Robotics Centre (Schweizerische Drohnen- und Robotik- Zentrum, SDRZ) is the branch of armasuisse (defence procurement agency) that works with the Swiss armed forces to evaluate, develop and field innovative robotic equipment for military purposes.[877] It is a practical study centre that centralises expertise that in most countries is dispersed among various institutions. Compared to other countries, Switzerland has an excellent network of government-supported, industry-related academic institutions. This goes hand in hand with Switzerland's being ranked among the top five countries in the world for the quality of its infrastructure, public finances and education system.[878] As one briefing paper

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[869] Dutta, Soumitra, et al. Global Innovation Index 2022., *World Intellectual Property Organization (WIPO),* 2022.: 19-22.
[870] World University Ranking, *Times Higher Education*, https://www.timeshighereducation.com/world-university-rankings/2023/subject-ranking/engineering-and-it. (Accessed on 08.03.2023)
[871] Research and Innovation in Switzerland 2020, *State Secretariat for Education, Research and Innovation (SERI)*, Federal Department of Economic Affairs, Education and Research (EAER), 2020.: 17.
[872] Recherche et développement en Suisse 2019, *Office Fédéral de la Statistique (OFS)*, Département Fédéral de l'Intérieur (DFI), 2019.: 16.
[873] *Ibid.:* 5.
[874] Switzerland – At the Forefront of Drone Technology, Factsheet, *Switzerland Global Enterprise*, 2022.: 2.
[875] *Ibid.*
[876] Swiss Robotics Ecosystem, *Swiss National Centre of Competence in Research (NCCR)*, https://nccr-robotics.ch/knowledge-and-tech-transfer/swiss-robotics/. (Accessed on 07.03.2023)
[877] Schweizer Drohnen- und Robotik-Zentrum, armasuisse, *Eidgenössisches Department für Verteidgung, Bevölkerungsschutz und Sport (VBS)*, 2017.: 1.
[878] IMD World Competitiveness Booklet 2022, *IMD World Competitiveness Center*, 2022.: 107.

states: *"Because of its excellent technical universities, dynamic talent pool and experienced ecosystem, Switzerland has built a reputation as the "Silicon Valley of Robotics."*[879] While the number of ATITCs is purely indicative, Switzerland with its 16 ATITCs, is doing well in this area. However, the decentralised nature of Switzerland and its strong federalism increases the number of academic institutions and thus the number of ATITCs. However, it is clear that Switzerland has a real comparative advantage in drones and robotics, compared to a country like Poland, which has only one ATITC in each field.

As in many other countries, there are no exact figures on robotics spending in Switzerland, but two sources give an idea. The International Federation of Robotics Frankfurt (IFRF) points out that Swiss ATITCs have received a total of USD 34.4 million in funding for 2014-2017 and 22.4 million for 2018-2021, an average of USD 8 million per year in robotics funding.[880] For its part, the Drone Industry Association Switzerland (DIAS) argues that between 2010 and 2021, USD 214.6 million were invested in drone R&D in Switzerland (mainly small civilian models), an average of USD 19.5 million per year. These figures refer to investments in dual-use robotics, and it is well known that, robotics in general has a very strong dual-use character, which means that these investments overlap with the development of potential military applications.[881] Looking at these two figures, it can be assumed that robotics R&D in Switzerland is probably in the range of USD 10-25 million per year.[882] This figure, which includes the development of dual-use robots, is not perfect and should be taken as an indication rather than a precise measure allowing comparison with other countries. For example, Switzerland's annual expenditure on robotics R&D is comparable to that of Sweden (EUR 10-30 million) and not far from that of Italy (EUR 25-45 million). It is logically far behind the largest European countries, the UK (EUR 150 million) and Germany (EUR 70-100 million).

Defence industry ecosystem and military-related innovation

Switzerland's defence policy rests on two pillars, the second of which is a direct consequence of the first: neutrality and the national security requirement for an indigenous capacity to produce military equipment.[883] As mentioned above, neutrality means that Switzerland remains outside political and military alliances, leaving the Confederation as the sole authority capable of defending the country's territorial sovereignty. This gives rise to the concept of "armed neutrality", i.e., the idea that if Switzerland's neutrality is to be taken seriously, the Confederation must be able to enforce it, thanks to competent armed forces and to a defence industry that provides high quality equipment (Security-Related Technology and Industry or in German "Sicherheitsrelevanten Technolgien- und Industriebasis", STIB).[884]

Indeed, Swiss defence policy was intended to be independent and autonomous until the last decade of the Cold War, but since then, the downsizing of the armed forces has inevitably led to a decline in domestic demand. The defence industry has compensated for this shrinking domestic market by turning to foreign exports, focusing on some products while abandoning

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[879] Switzerland – A Global Hub for Drone Technology and Robotics, Factsheet, *Switzerland Global Enterprise*, 2020.: 1.
[880] World Robotics R&D Programs, Informational Paper, *International Federation of Robotics Frankfurt (IFRF)*, 2021.: 71.
[881] Interview at the SDRZ, 23 September 2022.
[882] Swiss Drone Industry Report 2021, *Drone Industry Association Switzerland (DIAS)*.: 16.
[883] Hartley, Keith, and Belin, Jean*. The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 282-283.
[884] Neutralité armée et service actif en Suisse, *Archives fédérales suisses*, https://www.bar.admin.ch/bar/fr/home/recherche/conseils-de-recherche/themes/la-premiere-guerre-mondiale-en-suisse/neutralite-armee-et-service-actif-en-suisse.html. (Accessed on 09.03.2023)

others, thus moving from a model of independence to one of interdependence: *"Historically, national autonomy required a domestic weapons industry but independence became 'too costly'".*[885] Another important consequence of Switzerland's neutrality is the strict export controls that the country must observe, including the 1907 Hague Convention, which stipulates that a neutral country may not export war material or ammunition to a belligerent in an interstate conflict.[886] This has recently attracted much attention in the context of the Russian-Ukrainian war, as Bern not only refuses to export weapons directly to Ukraine, but also does not allow third countries to send Swiss-made weapons indirectly.[887]

Switzerland's militia military system has long relied on its STIB to produce equipment such as rifles, armoured vehicles and tactical communications systems. In this respect, maintaining a functional and efficient defence industry is a central element of the country's overall security and defence policy.[888] However, it is clear that Switzerland is dependent on foreign sources to acquire high-end systems such as fighter aircrafts (F/A-18 and F-35s from the US), IFVs (CV90s from Sweden) or advanced UAVs (Hermes 900 from Israel's Elbit Systems).[889] Overall, Switzerland exports far more defence equipment than it imports: between 2000 and 2020, it exported CHF 5 billion worth of equipment while importing CHF 829 million, making it the 12th largest exporter in the world in 2019.[890] The destination of exports and the origin of imports also reflects Switzerland's foreign policy, which exports mainly to partners and countries with which it shares values (26% to the US, 15% to EU countries but also 21% to China) and imports from neighbors and other "friendly" democracies (29% from Sweden, 18% from Germany, 10% from France).[891] In addition, Switzerland applies an "offset strategy", which means that for every Swiss franc spent on foreign equipment, one franc is subsidised to the STIB.[892] The main objective of this strategy is to keep as much production capacity and know-how as possible in Switzerland in order to maintain an innovative, efficient and competitive defence industrial base and to avoid excessive dependence on foreign imports.[893] This is done both by providing financial support to Swiss companies and by giving them the opportunity to participate in important programmes, thus enabling technology transfer and access to new markets. A good example of this is Lockheed Martin's offer to set up a cyber centre of excellence in Switzerland with the Swiss start-up Nozomi and the Kudelski Group.[894]

Switzerland's policy of interdependence in the defence industry is not dissimilar to that of countries such as Sweden and Norway, which have sought to maintain significant production capabilities and scientific know-how on their soil. However, Sweden has been more successful than Switzerland in maintaining an indigenous industrial base, producing high-end military

885 Hartley, Keith, and Belin, Jean. *The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 282-283.
886 Loi fédérale sur le matériel de guerre (LFMG), 13 décembre 1996, 514.41.
887 Mackenzie, Christina. The cost of neutrality: Swiss defense industry 'just losing our market' amid Ukraine conflict, *Breaking Defense*, https://breakingdefense.com/2023/03/the-cost-of-neutrality-swiss-defense-industry-just-losing-our-market-amid-ukraine-conflict/, 8 March 2023. (Accessed on 10.03.2023)
888 Principes du Conseil fédéral en matière de politique d'armement du DDPS, *Département de la Défense, de la protection de la Population et des Sports (DDPS)*, 2018.: 7246.
889 Vestner, Tobias. "Die sicherheitspolitishce Bedeutung der schweizerischen Rüstungsindustrie", *Geneva Centre for Security Policy (GCSP)*, 2021.: 15.
890 SIPRI Military Exports Database, *SIPRI*, https://milex.sipri.org/sipri. (Accessed on 10.03.2023)
891 Vestner, Tobias. "Die sicherheitspolitische Bedeutung der schweizerischen Rüstungsindustrie", *Geneva Centre for Security Policy (GCSP)*, 2021.: 22-23.
892 Stratégie d'armement, *Département de la Défense, de la protection de la Population et des Sports (DDPS)*, 2020.: 11.
893 Breitmeier, Urs. "Das Schweizer STIB-Modell im internationalen Vergleich", *Stratos - Militärwissenschaftliche Zeitschrift der Schweizer Armee*, Schweizer Armee, 2-2021.: 66.
894 Langer, Marie-Astrid. Der F-35 bringt die Kampfjet-Gegner in Rage – und die Fans ins Schwärmen, *NZZ,* https://www.nzz.ch/technologie/f-35-bringt-kampfjet-gegner-in-rage-und-fans-ins-schwaermen-ld.1627450?reduced=true, 8 June 2021. (Accessed on 09.03.2023)

equipment domestically such as fighter aircraft (Gripen), artillery systems (Archer) and conventional submarines (Gotland-class).[895] Sweden's export position is less conservative than Switzerland's, which makes comparisons difficult. However, Swiss defence policy is much less ambitious than, for example, France's "strategic autonomy", which has sought to maintain indigenous production expertise across the entire spectrum of military capabilities, from rifles (Famas) to MBTs (Leclers), from Amphibious Assault Ships (AAS) (Mistral-class) to fighter aircraft (Mirage and Rafale). Due to the ever-increasing costs of R&D and production of high-tech equipment, even larger states are now involved in multinational projects and foreign procurements (as in the case of the Franco-German next-generation tank, the MGCS, mentioned above).[896]

The Swiss defence ecosystem consists of three main players: (1) the STIB, of which RUAG is a major component; (2) armasuisse, the government procurement agency; and (3) the Swiss Armed Forces. Switzerland's STIB is made up of a large number of SMEs and a few large companies, the best known of which are Pilatus, GDLES Mowag and Rheinmetall Air Defence.[897] Together, these companies provide products and services in most military fields and are sometimes subsidiaries of international groups. Most of the SMEs are mainly focused on the national market, while the large companies are mainly active abroad. They are usually linked to the US defence industry and the other defence ecosystems of European countries.[898] The case of RUAG is illustrative: until recently, it was a hybrid organisation playing on both sides of the fence. It was only in 2019 that the Federal Council decided to split RUAG into two distinct organisations: RUAG MRO (Maintenance, Repair and Overhaul), the main service provider for the Swiss armed forces, and RUAG International, a defence company focused on international activities.[899] The other main defence player is the federal administration, represented by armasuisse, Switzerland's procurement agency. Armasuisse's *cahier des charges* consists of procurement for the Swiss armed forces and support for the STIB, as well as the promotion of defence innovation.[900] Armasuisse works closely with all STIB actors and has significantly increased its collaboration with industrial groups with the ratification in 2015 of a public-private partnership with the Association for Swiss Industry Participation in Security and Defence Programmes (ASIPRO). This project aims to improve the management of offsets and to support private defence companies.[901] In 2021, armasuisse supported the STIB with CHF 18.7 million, and signed 236 contracts with research institutes and private defence companies.[902] Armasuisse also participates in the "Einstein network", organised by the State Secretariat for Education Research and Innovation (Sécrétariat d'Etat à la Formation, à l'Education, à la Recherche et à l'Innovation, SEFRI), to provide an inter-departmental platform for direct contract with research institutions and industry in order to respond directly to the needs of the Swiss armed forces.[903] The third major defence actor is the Swiss armed forces, which draw up an upstream wish list of equipment and capabilities requirements and

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[895] *Ibid.:* 73.
[896] Kurç, Çağlar, and Neuman, Stephanie G. "Defence Industries in the 21st Century: A Comparative Analysis." *Defence Studies* 17, No. 3, July 2017, 219–27.: 220.
[897] Defense Industry of Switzerland, *Armada International*, 2013.: 3.
[898] Hartley, Keith, and Belin, Jean*. The Economics of the Global Defence Industry*. New York: Routledge, Taylor & Francis Group, 2020.: 284.
[899] Le Conseil fédéral décide de l'avenir du groupe technologique RUAG, *Secrétariat d'Etat à l'Economie (SECO),* Département de l'Economie, de la Formation et de la Recherche (DEFR), https://www.seco.admin.ch/seco/fr/home/seco/nsb-news.msg-id-74367.html, 18 March 2019. (Accessed on 07.03.2023)
[900] Rapport annuel 2021 – Mise en oeuvre de la stratégie d'armement du DDPS, *armasuisse*, Département de la Défense, de la protection de la Population et des Sports (DDPS), 2021.: 2.
[901] Interview at the SDRZ, 23 September 2022.
[902] *Ibid.:* 16.
[903] Jahresbericht 2022 – Umsetzung der Rüstungsstrategie des VBS, *armasuisse*, Eidgenössisches Department für Verteidgung, Bevölkerungsschutz und Sport (VBS)*,* 2022.: 16.

tests the material downstream, through mechanisms such as the Advanced Robotic Capabilities for Hazardous Environment (ARCHE), events such as the 2021 Defence against Drones in Bure (Défense contre les drones à Bure 2021) or directly at RUAG MRO's MKZ (Materialkompetenzzentrum).[904] The Swiss armed forces also benefit from direct and indirect contacts with the STIB players through platforms set up by armasuisse such as the "Industry Orientation" (Industrieorientierung), DEFTECH-Days (Defence Future Technologies or the Cyber-Defence Campus).[905]

The main problem concerning defence-related innovation in Switzerland is therefore not the country's ability to develop pioneering cutting-edge technologies, but the mismatch between the Swiss armed forces' needs of the Swiss armed forces and the STIB's to engage in a sustained effort to adapt dual-use technologies for military applications.

Defence innovation in Switzerland, as in most other countries, depends heavily on the development of dual-use technologies from the civil sector and private industry. Although Switzerland's top innovation capacities theoretically put it into a leading position to harvest defence-related innovation, the Swiss armed forces have not much benefited from this potential. In fact, the way innovation works has changed significantly with the advent of 4IR technologies. A few decades ago, innovation was mainly driven by top-down projects articulated by the defence and supported by governmental subsidies, whereas today innovation is bottom-up, through spill-overs from SMEs and start-ups.[906] However, *"(…) these civilian companies are no longer automatically recognised and recorded as part of the STIB. On the other hand, many of these companies find it difficult to seek access to the defence technology market on their own."*[907] Switzerland faces a somehow similar problem to Germany and its "firewall" between civilian and military applications. The field of small UAVs is a telling example of the inability of the defence sector to take advantage of the country's innovation potential. In fact, Switzerland is a world leader in this field, with ETHZ's ASL and EPFL's LIS being two of the leading players in the development of small drones. However, as most of the start-ups involved in the development of these UAVs do not consider defence applications for their products as a priority, their valuable work does not benefit the military. The result is the paradoxical situation in which Armasuisse has to procure foreign-made drones to the Swiss armed forces despite having the best innovative capabilities in small UAVs.[908]

The main problem with defence innovation in Switzerland is therefore not the country's ability to develop cutting-edge technologies, but the mismatch between the needs of the Swiss armed forces and the willingness of the STIB to make a sustained effort to adapt dual-use technologies for military applications. As one expert puts it: *"Especially in the field of new technologies, there are few companies that are interested in entering the defence technology business."*[909] The Swiss administration has recently taken measures to remedy the situation,

[904] Umfassendes Life-cycle Management von Waffensystemen, *RUAG*, https://www.ruag.ch/de/unsere-kompetenzen/fahrzeugintegrationen (Accessed on 10.03.2023)
[905] Jahresbericht 2022 – Umsetzung der Rüstungsstrategie des VBS, *armasuisse,* Eidgenössisches Department für Verteidgung, Bevölkerungsschutz und Sport (VBS), 2022: 17.
[906] Fuhrer, Daniel and Lutz, Martin. "Die längerfristige Ausrichtung der Armee vor dem Hintergrund einer fähigkeitsorientierten Streitkräfteentwicklung", *Stratos - Militärwissenschaftliche Zeitschrift der Schweizer Armee,* Schweizer Armee, 1-2021.: 34.
[907] Breitmeier, Urs. "Das Schweizer STIB-Modell im internationalen Vergleich", *Stratos - Militärwissenschaftliche Zeitschrift der Schweizer Armee*, Schweizer Armee, 2-2021: 70. Translation by the authors
[908] *Ibid.:* 72.
[909] *Ibid.*

with the ongoing establishment of an organisation called “Swiss Innovation Forces” (SIF), aiming at supporting the development of defence innovation projects.[910] Figure 34 below notably compares the Swiss system with its European and NATO equivalents.

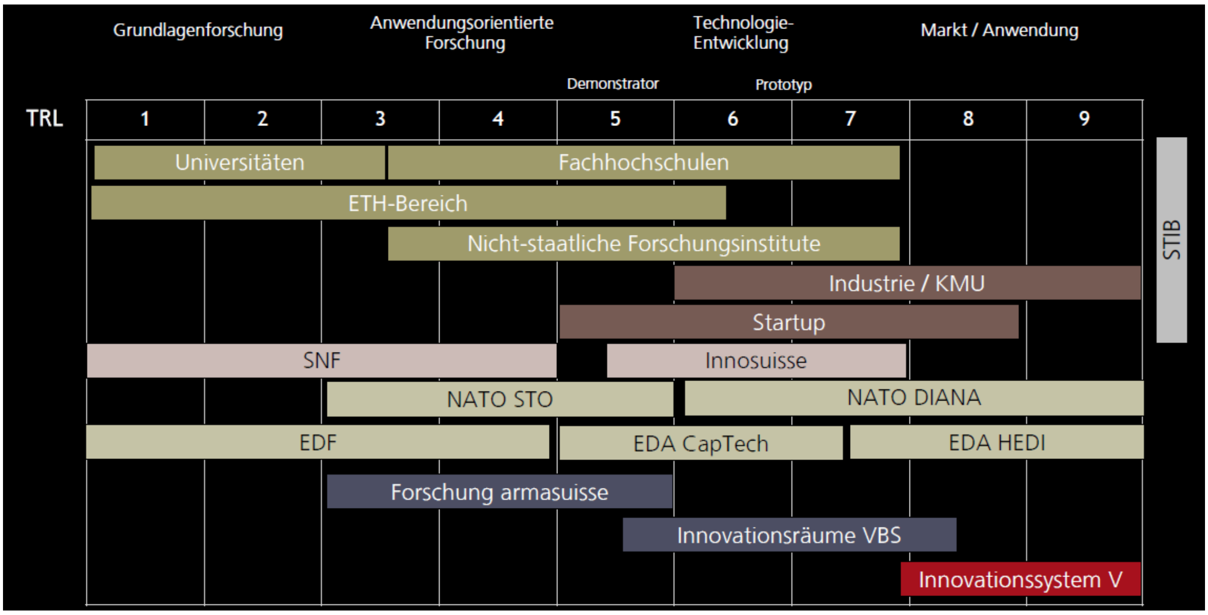

Figure 34 - Switzerland civilian-military innovation environment.

As a non-member of NATO and the EU, Switzerland does not take part in many supranational defence R&D and production projects. As far as NATO is concerned, Switzerland usually tries to use STANAG standards, not only for reasons of interoperability, but mainly because the weapons and equipment it exports are destined for NATO countries. Thus, the institutional development of NATO in defence-related innovation generates opportunities for Switzerland. On the one hand, the transatlantic organisation, with INF and DIANA, is of particular interest to Switzerland even though it is not a member. On the other hand, Bern’s status as an innovation champion would be warmly welcomed by NATO, thus enhancing the alliance’s innovation capabilities.[911] More generally, Switzerland would benefit from the advice and expertise of NATO Industrial Advisory Group’s (NIAG) on relevant elements of R&D and armaments production.

As defence-related innovation projects require long-term commitments and substantial funding sometimes exceeding national resources, the emergence of an increasingly integrated transatlantic framework for military R&D is good news for Switzerland. However, deeper integration into the transatlantic defence system would require a strong political commitment on the part of Switzerland, which would represent a departure from its current foreign policy. In terms of EU institutions and initiatives, Bern has a better chances of being involved, as it is a member of the EDA, and is currently involved in six Capability Technology Groups (CapTechs).[912] However, the strengthening of members-only institutions such as PESCO, EDIDP and PADR means that Switzerland will simply be side-lined as long as it is not a member of the EU. Yet other venues, such as HEDI, designed as a platform to bring together

[910] Innovation für die Armee, Das Innovationssystem Verteidigung und die Swiss Innovation Forces, *Schweizerische Gesellschaft für Technik und Armee (STA)*, https://www.sta-network.ch/innovationstag-15-09-2023/, 15 September 2023. (Accessed on 04.10.2023)
[911] Larsen, Henrik. “Die Schweiz und die NATO: neue Konvergenz.” *Center for Security Studies (CSS)*, ETH Zurich, 11 December 2019.: 69.
[912] “Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung", CSS Briefing-Paper, *Center for Security Studies (CSS)*, ETH Zurich, August 2022.: 11.

private actors, government institutions, start-ups and academia to develop EDTs represent an opportunity for Switzerland, as the aim of this organisation would fit very well with the Swiss innovation environment. The further development of HEDI is therefore of particular interest to Switzerland.

In summary, the impact of the third and fourth innovation drivers – namely (3) innovation organisation and governance and, (4) investment in defence-related innovation – are assessed. With regards to (4), Switzerland invests heavily in defence-related R&D, as CHF 79 million were invested in 2017 and CHF 103 million in 2019, with an annual growth rate of 15%. Switzerland has excellent infrastructures and educational system that supports innovation, with a world-class network of ATITCs that is almost unrivalled in Europe. For these reasons, Switzerland, despite its small size, ranks atop Europe's "middle powers", ahead of countries such as the Netherlands, Sweden and Norway. With regard to (3), Switzerland's industrial policy is confined by its strict policy of neutrality. A network of diversified SMEs and large defence multinationals, together with the ATITCs, make up a competitive STIB, which retains crucial know-how on Swiss territory while being interdependent with foreign defence actors. The STIB works well with the two other main players in the defence ecosystem, armasuisse and the Swiss armed forces. If this triangular cooperation is to evolve towards greater interpenetration and cooperation, much remains to be done in this area. The main problem lies in the fact that armasuisse and the Swiss Armed Forces have so far not been able to attract the most innovative components of the STIB, mainly start-ups and companies focused on EDTs. By failing to attract Switzerland's leading innovators in dual-use technologies and to involve them in defence-related projects, the Swiss authorities will not be able to fully exploit the country's innovation potential. Therefore, (4) drives innovation strongly, while (3) does so with medium intensity.

Doctrinal developments and military robotics

Switzerland's military doctrines and their legacy

Swiss military doctrine is a challenging subject because, it treats an object – the Swiss armed forces – that has never fought a war, apart from the brief civil war of the Sonderbund. The progressive development of Swiss military doctrine must always be considered in this context and remains basically an intellectual exercise, without the benefit of direct experience in the field.[913] This means that the Swiss armed forces have always relied on observing the doctrines of foreign armed forces to improve, test and incorporate innovations into their own. This approach is pragmatic, as it seeks to adapt to trends and developments observed in foreign conflicts, to draw conclusions and provide guidance adapted to the Swiss context.[914] However, this method of thinking, testing and implementing doctrinal developments is designed to be incremental rather than disruptive. In addition, this approach is inherently more practical and observational than based on deep theoretical thinking: *"In the typical Swiss way, this process is quite pragmatic, without too much worrying about the spiritual fathers of doctrines and principles."*[915]

[913] Meier, Claude. *150th Anniversary Celebration of the Life and Legacy of General Antoine-Henri Jomini, 1779-1869*. Washington, DC: Embassy of Switzerland in the United States of America, 2019.: 35.
[914] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.
[915] Meier, Claude. *150th Anniversary Celebration of the Life and Legacy of General Antoine-Henri Jomini, 1779-1869*. Washington, DC: Embassy of Switzerland in the United States of America, 2019.: 35.

As a result, the doctrinal thinking of the Commander-in-Chief, in the Swiss case the Chief of the armed forces (CdA), tends to have little impact on operational and tactical doctrine because the Swiss approach does not allow for innovative and disruptive ideas. As proof, none of the four Swiss officers who have reached the rank of general (four stars) is known for a particular doctrine or way of conducting war, and the only distinguished military thinker Switzerland has, General Antoine-Henri Jomini, served in foreign armies.[916] Finally, Switzerland's approach to military doctrine development is reactive rather than anticipatory, meaning that it is always catching up with newly observed phenomena and trends, with the potential risk of missing important developments.

This concept of "Schwergewichtsbildung" is still very influential in Swiss military doctrine today (…) as the Swiss armed forces are essentially designed to fight a short, decisive war of manoeuvre in which a rapid and conclusive conventional superiority will turn the tide.

Three main periods and concepts of the Swiss armed forces continue to influence the current doctrine: (1) WWI and WWII reluctance to draw up operational plan for Swiss defence, based on General Wille's embrace of the Prussian General von Moltke's tradition emphasising adaptability[917], (2) Cold War era doctrine based on the importance of mobile defence and air-land battle, influenced by the writings of French General André Beauffre[918] and, (3) post-Cold War era doctrine fed by Jomini's concept of *Schwergewichtsbildung*, or the idea that military superiority is relative to the concentration of power at the right time.[919] This concept of *Schwergewichtsbildung* is still very influential today in Swiss military doctrine today, and relies on three main components: (1) initiative as a decisive factor, (2) mobility and movement as the key to dominating the enemy and, (3) the maximum concentration of forces to maximise mass and inflict irreparable losses.[920] The Swiss armed forces are essentially designed to fight a short, decisive war of manoeuvre in which a rapid and decisive conventional superiority will turn the tide.[921] Such a doctrinal posture implies a technologically advanced military force capable of detecting and neutralising an enemy that is more numerous but less sophisticated on the technological spectrum. Military robotics is therefore an area of real interest for the Swiss armed forces.

For at least a decade, the Swiss armed forces have been considering how to best integrate robotic systems into its force structure. However, there is no doctrine or reference document detailing how this integration should be implemented. Furthermore, according to a senior Swiss officer, the issue of the integration of military robotics into the Swiss armed forces is not considered a doctrinal issue, but rather one of "operating procedures" (Einsatzverfahren).[922] This reflects the practical and adaptive approach described above and means that the Swiss

[916] Swain. Richard. "The Hedgehog and the Fox": Jomini, Clausewitz, and History", *Naval War College,* Volume 33, Number 4 Autumn, Article 8, 1990, 98-109.: 104.
[917] Daniel J. Hughes. *Moltke on the Art of War Selected Writings*, Presidio, 1996.
[918] Shurkin, Michael. Grand Strategy is Total. French Gen. André Beaufre on War in the Nuclear Age, *War on the Rocks*, https://warontherocks.com/2020/10/grand-strategy-is-total-french-gen-andre-beaufre-on-war-in-the-nuclear-age/, 8 October 2020. (Accessed on 17.03.2023)
[919] Meier, Claude. *150th Anniversary Celebration of the Life and Legacy of General Antoine-Henri Jomini, 1779-1869*. Washington, DC: Embassy of Switzerland in the United States of America, 2019.: 37.
[920] Gat, Azar. *A History of Military Thought: From the Enlightenment to the Cold War*. Oxford ; New York: Oxford University Press, 2001.: 118.
[921] Conception de l'Armée – Résumé des trois rapports fondamentaux : Avenir des forces terrestres, Avenir de la défense aérienne, Conception générale cyber. *Département de la Défense, de la protection de la Population et des Sports (DDPS),* 2022.: 16. Translation by the authors.
[922] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.

armed forces assess where it needs to integrate robotic systems on a functional basis. More specifically, the analysis of doctrinal developments in military robotics is divided into the two main categories of systems that Switzerland currently operates and is likely to field in the future: UAVs and UGVs. As Switzerland does not have a navy – besides the 16 patrol boats of the Boat Company 10 (Motorbootkompanie 10, Genietruppe) – it is unlikely to invest much in developing doctrinal concepts for UMSs.[923] UAVs are a more mature and established market, particularly in Switzerland, where the armed forces operated the Ranger UAV since 1999, so it is logical that the doctrinal thinking on UAVs is richer.[924] UGVs are an emerging subject of reflection that is likely to become more prominent in the years to come.

Evolution of Swiss doctrine in military robotics

In the absence of a proper military doctrine specifying the use of robotics, the Swiss DDPS has published two important documents that provide a frame on the use of these systems: the Future of Air Defence in 2017 (*Luftverteidigung der Zukunft*) and the Future of Land Forces in 2019 (*Zukunft der Bodentruppen*).[925] These two documents focus on the assessment and development of forces and capabilities as well as on the acquisition of new equipment. Overall, UAVs and UGVs have five main missions: (1) reconnaissance and raising situational awareness, (2) protection of the force, (3) resupply, (4) evacuation of wounded personnel and, (5) preventive maintenance.[926] The aim is to integrate robotic systems progressively to all levels of the force, as and when required.[927]

Only tasks that put humans in harm’s way, such as demining, surveillance in contested environments, etc., may potentially be delegated exclusively to robots in the future. Otherwise, the human will remain in the loop, which means that the Swiss armed forces are not looking for fully autonomous systems. Above all, the Swiss armed forces require robotic systems to be highly adaptable and modular, able to perform tasks in a wide variety of missions and to work in teams with human soldiers.[928] As the Future of Land Forces in 2019 puts it: *“The use of autonomous systems can help save forces in multiple scenarios, such as defence against an armed ground attack or reconnaissance of unconventional forces in a complex engagement environment, but the number of troops and the quality of engageable weapon systems remain decisive.”*[929]

As mentioned above, UAVs are the robotic systems with which the Swiss armed forces have the most experience in using. They are primarily used for ISR and C4 missions, at most levels of the armed forces. Class II and III drones (over 150 kg) are used by the Swiss air force for surveillance, intelligence and communication support, as HALE and MALE systems can stay airborne for long periods of time (16-24h). This endurance strengthens the air force’s

[923] Armee Einsatz auf dem See | 360°-Video auf dem P16 | Blick, *Youtube*, https://www.youtube.com/watch?v=aVm2Q4uBBnQ, 3 November 2019. (Accessed on 17.03.2023)
[924] Ranger Tactical Unmanned Aerial Vehicle (UAV), *Airforce Technology*, https://www.airforce-technology.com/projects/rangerunmannedaerial/, 12 December 2010. (Accessed on 20.03.2023)
[925] Luftverteidigung der Zukunft*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2017.; Zukunft der Bodentruppen*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2019.
[926] Zukunft der Bodentruppen*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2019.: 48.
[927] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.
[928] Langfristiger Forschungsplan (LFP) 2021-2024 – Forschungskonzept armasuisse mit Forschungsschwerpunkten und prioritären Themen, *armasuisse*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS).: 71.
[929] Zukunft der Bodentruppen, *Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS),* 2019.: 48. Translation by the authors.

capabilities, and overall, these UAVs are seen as complementary to ISR assets such as satellites and manned aircrafts.[930] The Swiss armed forces are currently replacing their aging fleet of Ranger with 6 Hermes 900. The missions of drones could basically also include kinetic missions such as airstrikes in the context of a conflict, but the possibility of having armed UAVs is strictly limited to this condition.[931] Unfortunately, the option of arming the Hermes 900 was ruled out by Switzerland for political reasons. To be effective, UAVs must be integrated into the broader air defence concept alongside fighter jets and other Anti-Aircraft Warfare (AAW) assets. Only in this measure drones can be useful tools for reducing the enemy's mobility in the event of an armed conflict. The Swiss acquisition of the F-35 multi-role fighter is a further indication of the Swiss Armed Forces' desire to create synergies between manned and unmanned air systems to obtain the most effective force possible.[932]

Above all, the Swiss armed forces require robotic systems to be highly adaptable and modular, able to perform tasks in a wide variety of missions and to work in teams with human soldiers.

Class I drones (mini- and micro-drones, weighting less than 150 kg) will be used primarily by the three main categories of land forces: artillery, armoured mechanised units and infantry. To improve the capabilities of these units, "MiniDrohne Schweizer Armee" programme was announced back in 2015.[933] In this context, Switzerland has observed what has been done in recent conflicts (Nagorno-Karabakh, Syria, Ukraine) and how NATO armed forces have integrated smaller types of drones into their armed forces. However, as experts point out: *"(…) the introduction of drones for a defensive army is not trivial and lessons that are highly relevant in the NATO framework are not necessarily applicable to Switzerland."*[934] The artillery is expected to use tactical and miniature drones as a means of increasing situational awareness and precision strike. This is typically one of the early lessons of the Russo-Ukrainian war: coupled with effective intelligence tools such as drones, even older types of artillery systems can be transformed into lethal precision strike instruments.[935] Infantry and armoured mechanised units are more likely to use mini- and micro-drones, as these front-line fighting units will have less space to carry larger systems and as they will mostly need tactical intelligence to conduct their operations. No kinetic applications are foreseen for these UAV systems in the land forces.

By way of illustration, the Infantry Battalion 19 (Battaillon d'infanterie 19) has started training on Anafi SE multicopters during the 2022 refresher course.[936] However, the Swiss armed forces have not yet defined how the integration of mini- and micro-drones will affect the

[930] Conception de l'Armée – Résumé des trois rapports fondamentaux : Avenir des forces terrestres, Avenir de la défense aérienne, Conception générale cyber. *Département de la Défense, de la protection de la Population et des Sports (DDPS),* 2022.: 27.
[931] Luftverteidigung der Zukunft*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2017.: 39.
[932] Conception de l'Armée – Résumé des trois rapports fondamentaux : Avenir des forces terrestres, Avenir de la défense aérienne, Conception générale cyber. *Département de la Défense, de la protection de la Population et des Sports (DDPS),* 2022.: 129-130.
[933] Werden Minidrohnen die neuen Kundschafter der Schweizer Armee?, *Watson*, https://www.watson.ch/schweiz/armee/283259848-werden-minidrohnen-die-neuen-kundschafter-der-schweizer-armee, 28 March 2015. (Accessed on 11.04.2023)
[934] Despont, Constant et al. "Militärische Drohnennutzung: Erfahrungen, Technolgie und Schweizer Optionen", *Center for Security Studies (CSS),* Bulletin 2022 zur Schweizerischen Sicherheitspolitik, 2022.: 56.
[935] Suciu, Peter. New Footage Shows Ukraine Using Drones And Artillery To Hit Russian Tanks, *1945*, https://www.19fortyfive.com/2023/03/new-footage-shows-ukraine-using-drones-and-artillery-to-hit-russian-tanks/, 6 March 2023. (Accessed on 20.03.2023)
[936] Armée Suisse Bat inf 19 - SIF 2022, *Youtube*, https://www.youtube.com/watch?v=nDlupJ_b_7I, 9 September 2022. (Accessed on 20.03.2023)

composition of an infantry squad, as it has been the case in certain foreign armies with the emergence of a kind of "droneman".[937] The Mechanised Battalion 17 (Bataillon mécanisé 17) used Black-Hornet microdrones during its annual training 2021 and 2022.[938] The Black-Hornet is a nano-helicopter capable of flying for 25 minutes at a speed of up to 25 km/h and recording live-stream for a single individual operator both day and night. An extremely lightweight system (weighing 33g, 4 inches long), the Black-Hornet would be suitable for mechanised infantry teams already carrying heavy equipment such as anti-tank weapons, explosives or engineering equipment.[939] The Swiss militia's system allows for useful learning and adaptation processes, as well as a smooth integration of these systems at most force levels through means such as the Advanced Robotic Detachment (ARDET) and refresher courses.[940] As experts argue: *"In order to achieve an ideal, multifaceted coverage, drones are therefore necessary at different organisational levels."*[941] This is particularly true of the Swiss integration scheme, which is practice- and requirement-driven, ensuring bottom-up adaptability from groups, platoons, companies, and battalions.[942]

At the same time, Switzerland is considering measures to combat drones. In 2021, the Federal Council published a report on the security of Switzerland with regards to drone technology *(Rapport sur la sécurité de la Suisse eu égard à la technologie des drones)*, to clarify how Switzerland intends to respond to the new security threats posed by UAVs.[943] According to the document, the aim of counter-drone warfare is to deny an enemy air superiority and allow the air force to conduct missions with jets and drones in its own airspace.[944] To defend against Class II and III drones, the Swiss armed forces will engage traditional means such as anti-aircraft guns, surface-to-air missiles, fighter jets or jamming effectors.[945] As the behaviour of these systems is more predictable, it is easier to defend against them. Defending against Class I drones is a more immediate concern, as these systems are more unpredictable and can operate with limited resources.

Countering these smaller UAVs is the responsibility of the Swiss armed forces, as well as the police and the border control. The stated "operating procedures" consist of three successive objectives: (1) identification, (2) localisation and, (3) suppression of the threat.[946] To achieve (1) and (2), the Swiss authorities expect that foreseeable developments in sensors, AI-driven algorithms and quantum computing will facilitate the task. With regards to (3), the Swiss armed forces can use both non-kinetic and kinetic means. Non-kinetic means include jamming of radio frequencies and satellite-communications. Kinetic means include net launchers,

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[937] Sanchez, Wilder Alexandro. How will drones affect infantry tactics?, *Defence IQ*, https://www.defenceiq.com/defence-technology/articles/how-will-drones-affect-infantry-tactics, 14 March 2019. (Accessed on 21.03.2023)

[938] Bataillon mécanisé 17 - SIF 2022 review, *Youtube,* https://www.bing.com/videos/search?q=bataillon+m%c3%a9casni%c3%a9+17+sif&view=detail&mid=FE80F7099121DAA5D85DFE80F7099121DAA5D85D&FORM=VIRE, 12 August 2022. (Accessed on 20.03.2023)

[939] Sanchez, Wilder Alexandro. How will drones affect infantry tactics?, *Defence IQ*, https://www.defenceiq.com/defence-technology/articles/how-will-drones-affect-infantry-tactics, 14 March 2019. (Accessed on 21.03.2023)

[940] Swiss Drones and Robotics Centre (SDRC), *armasuisse*, https://www.ar.admin.ch/en/armasuisse-wissenschaft-und-technologie-w-t/sdrz.html. (Accessed on 11.04.2023)

[941] Despont, Constant et al. "Militärische Drohnennutzung: Erfahrungen, Technolgie und Schweizer Optionen", *Center for Security Studies (CSS),* Bulletin 2022 zur Schweizerischen Sicherheitspolitik, 2022.: 57.

[942] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.

[943] "La sécurité de la Suisse eu égard à la technologie des drones", Rapport du Conseil fédéral en réponse au postulat 21.3012 CPS-N du 25 janvier 2021, *Conseil Fédéral,* 2021.

[944] Luftverteidigung der Zukunft*, Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2017.: 48.

[945] "La sécurité de la Suisse eu égard à la technologie des drones", Rapport du Conseil fédéral en réponse au postulat 21.3012 CPS-N du 25 janvier 2021, *Conseil Fédéral,* 2021.: 15.

[946] *Ibid.:* 13.

fragmentation shotguns, small-calibres anti-aircraft canons and possibly in the future, high-energy laser weapons.[947] Counter-drone warfare remains problematic for the Swiss armed forces, especially with regard to smaller types of UAVs, and the adaptation of "operational procedures" is not yet satisfactory.

With regards to UGVs, the Swiss armed forces are gradually developing an understanding of how these systems can be used and integrated. The publication Future Conception of the Armed Forces 2022 (*Conception Avenir de l'Armée*) stated that the development of autonomous ground systems will have a major impact on the way ground operations will be conducted in the future.[948] The Future of Land Forces 2019 specifies that UGVs are used for nine different military tasks: (1) demining, (2) reconnaissance, (3) surveillance, (4) rescue, (5) transport, (6) firefighting, (7) communications relays, (8) electronic warfare platform and (9) NRBC protection.[949] Overall, UGVs are seen as instruments to facilitate dangerous missions and keep operators out of harm's way. Their use is always considered in conjunction with manned vehicles such as MBTs, IFVs or APCs.

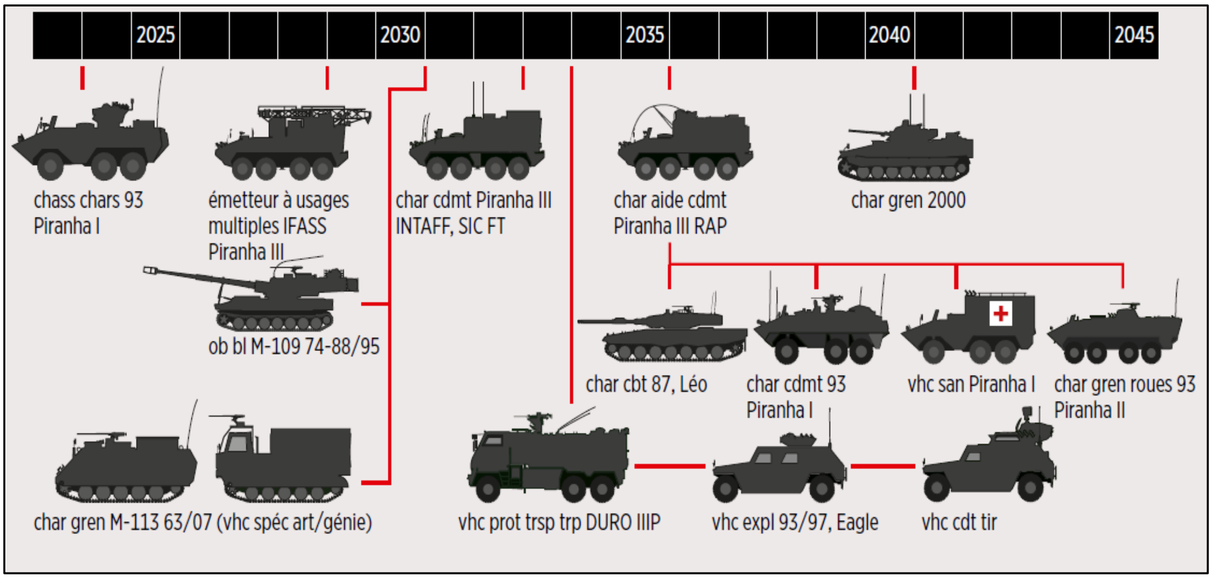

Figure 35 - Forecasted end date of use of selected core systems of Switzerland's land forces.[950]

UGVs are increasingly seen as having the potential to enhance existing capabilities and even replace certain segments of capabilities: *"From the late 2020s onwards, technological breakthroughs will be able to advance ground systems, as was the case some 20 years ago in the field of air force systems (autonomous systems, enhanced networking, swarms, artificial intelligence). Long-term planning must be flexible enough to accommodate such innovations."*[951] This is a relevant point, as Figure 35 illustrates that most of the land forces' core equipment will be replaced between 2025 and 2045. The most important systems of the

[947] 10 Counter-Drone Technologies to Detect and Stop Drones Today, *Robin Radar Systems*, https://www.robinradar.com/hubfs/RBR%2010%20Counter%20Drone%20Technologies%20Ebook.pdf. (Accessed on 20.03.2023)
[948] Conception de l'Armée – Résumé des trois rapports fondamentaux : Avenir des forces terrestres, Avenir de la défense aérienne, Conception générale cyber. *Département de la Défense, de la protection de la Population et des Sports (DDPS)*, 2022.: 16.
[949] Zukunft der Bodentruppen, *Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2019.: 39.
[950] Conception de l'Armée – Résumé des trois rapports fondamentaux : Avenir des forces terrestres, Avenir de la défense aérienne, Conception générale cyber. *Département de la Défense, de la protection de la Population et des Sports (DDPS)*, 2022.: 7.
[951] *Ibid.:* 134. Translation by the authors.

Swiss land forces will soon enter their end-of-life cycle: the M109 howitzer "ob bl M109 17/88-95" in 2030, the Leopard 2 MBT "char cbt 87" in 2035 and the CV90 IFV "char gren 2000" in 2040. These systems have already undergone several phases of upgrading and it is stated that the acquisition of new systems is a priority, as equipment that has been in service for 40 or 50 years can only be upgraded at a cost that would exceed that of a new acquisition.[952] In the case of the Leopard 2 MBT, for example, it is considered that *"(…) a replacement will have to be considered in the 2030s, when new technologies may be available (e.g. joint engagement of unmanned systems)."*[953]

The Swiss land forces do not yet envisage any direct combat roles for UGVs such as fire suppression or fire attack. However, as UGVs are seen as valuable systems to be coupled with combat vehicles such as MBTs, IFVs and units such as mechanised infantry, they would potentially be tasked with non-combat missions such as breaching, team support, support mobility and squad following.[954] UGVs are also seen as systems that are easier to operate in urban environments, making them more suitable for a potential future battle to defend Switzerland's increasingly populated environment.[955] At the tactical level, however no decision has been taken on how to integrate humans and robots within companies, sections, platoons and squads. The Swiss armed forces are likely to follow their practice- and requirement-driven approach and deploy robots at the levels where they are the most effective and the most relevant. However, it is also recognised that most UGVs cannot currently compete with manned systems and should therefore be seen as augmenting rather than replacing manned capabilities.[956] The only units that currently use regularly UGVs in the Swiss armed forces are the Rescue Troops (Rettungstruppe), to support civilian authorities in the event of environmental disasters.[957]

The strict ethical and moral considerations related to the issue of autonomous systems, often referred to in the media as "killer robots" or "terminator" constitute an important limitation to be taken into account for the further implementation of military robotics in the armed forces. On the one hand, Switzerland has made it clear that it is against the proliferation of autonomous weapons.[958] But on the other hand, Bern's position is ambiguous, as it has refused to support a total ban on Lethal Autonomous Weapon Systems (LAWS): *"According to Bern, the risk is that potentially useful systems, such as those that prevent collateral damage to the population, will be banned."*[959] Switzerland does not want to be seen as supporting the democratisation of LAWS, but remains opposed to an outright ban on autonomous military systems that could be tactically useful for the functions described above.[960] However, a recent study conducted by the University of Zurich and SDRZ has highlighted that both the "desirability" and the "potential" of integrating military robotic systems

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[952] *Ibid.:* 142.
[953] *Ibid.:* 135.
[954] Zahradnicek, Pavel and Rak, Ludek. "Combat UGV: The Challenge of Their Implementation in Combat Units." *International Conference Knowledge-Based Organization,* Vol. 27, No. 3, 2021: 105–109.: 107.
[955] Honegger, Lorenz. Roboter statt Panzer: Viola Amherd will 15 Milliarden für neue Waffensysteme ausgeben, *Aargauer Zeitung,* https://www.aargauerzeitung.ch/schweiz/roboter-statt-panzer-viola-amherd-will-15-milliarden-fur-neue-waffensysteme-ausgeben-ld.1364230, 17 May 2019. (Accessed on 22.03.2023)
[956] Schroeder, Ted. "Robotics in Infantry Battalions", *Marine Corps Gazette*, 2017.: 12.
[957] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.
[958] Mayer, Marguerite and Lüthi, Ariane. «Wir wollen keine Killerroboter», *Blick,* https://www.blick.ch/schweiz/nachgefragt-bei-eda-mann-reto-wollenmann-ueber-die-haltung-der-schweiz-zu-killerrobotern-wir-wollen-keine-killerroboter-id18227881.html, 15 january 2023. (Accessed on 24.03.2023)
[959] Bondolfi, Sibilla and Ibrahim, Sara. L'interdiction des robots tueurs se joue à Genève, *Swissinfo.ch*, https://www.swissinfo.ch/fre/economie/l-interdiction-des-robots-tueurs-se-joue-%C3%A0-gen%C3%A8ve/47689256, 23 June 2022. (Accessed on 23.03.2023)
[960] Kunertova, Dominika. "From Robots to Warbots: Reality Meets Science Fiction." *Center for Security Studies (CSS)*, ETH Zürich, October 2021.: 3.

into the Swiss armed forces is very high among officers and members of the SOG.[961] A balance between Switzerland's international engagement and its defence requirements will need to be found.

Investments and markets of military robotics in Switzerland

Switzerland's advances in UAVs

As noted earlier in this chapter, Switzerland has become increasingly interested in the R&D and deployment of military robotic systems, a trend that is confirmed by the country's investment and market size in this area (Figures 36 and 37 below). As in most of the countries analysed so far, the main military robotics area in Switzerland is UAVs, with a market that is expected to grow from USD 48.5 million in 2022 to 80.6 million in 2025.[962] This figure is significantly influenced by the purchase of six Hermes 900 (ADS 15) from Elbit, at an estimated price of several tens of millions of USD each (price spread over the twenty years or more of the use of the drone). This system will be the only Class III UAV purchased by Switzerland and used by its armed forces. In parallel, the "MiniDrohne Schweizer Armee" programme included the purchase of four other micro- and mini-drones: the Black Hornet, the Anafi SE, the Indago and the Orbiter 2b (see Figure 28).[963] The Anafi SE is a 320g drone that can operate for 25 minutes autonomously within a 4 km radius. The Indago 3 by Lockheed Martin weighs 3kg and can stay in the air for 45 minutes, fly up to 10 km away from its base and has very precise thermal optics. Finally, the Orbiter 2b is a tactical drone equipped with high-end ISTAR and capable of operating within a radius of up to 100km.[964] These four tactical systems cover all force levels, from the individual soldier with the Black Hornet, to the team leader with the Anafi SE and to the platoon leader and company commander with the Indago and the Orbiter.[965] Figure 36 below shows the Swiss market size by type of military robotic platforms between 2022 and 2025.

Platforms	2022	2023	2024	2025	CAGR (2020-2025)
UAVs	49	60	69	81	18.6%
UGVs	7	10	13	18	37.1%
UMSs	3	4	6	7	32.6%
Total	**59**	**74**	**88**	**106**	**21.6%**

Figure 36 – Switzerland military robotic and autonomous systems market, USD million.[966]

[961] Christen, Markus and Vöros, Pascal. "Welche autonomen Roboter braucht die Schweizer Armee", *Allgemeine Schweizerische Militärzeitschrift (ASMZ)*, 2023.: 34.
[962] Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; 117.
[963] Gisler, Simon. "Neue Mini-Drohnen für die Bodentruppen der Schweizer Armee", *armafolio 1/2022*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2022.
[964] *Ibid.:* 12-13.
[965] *Ibid.:* 10.
[966] Figure made by the authors. *Sources*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A

In addition, Switzerland is also developing various types of UAVs with different military applications through close collaboration between its ATITCs, defence contractors, procurement agency and the armed forces. Information provided by the SDRZ and armasuisse describes at least thirteen different UAVs at various stages of development (TRLs 1-9), all belonging to Class I (see Figure 36). The Voliro Hexacopter from ASL and Voliro Airborne Robotics is an omnidirectional system capable of going to places inaccessible and dangerous for humans, recording measures and livestream video feeds.[967] The next three drones are counter-UAV systems, designed to detect, catch and neutralise threats posed by mini-drones. The Peregrine from ASL and DroGone is a drone-catcher capable of retrieving its target without damaging it. The system is partly autonomous in that it can catch a UAVs on its own once the target has been identified.[968] The Peregrine has the potential to become a useful counter-UAV instrument to protect the lower levels of the airspace. The Mobula is a high-speed, horizontal take-off counter-UAV drone developed by the Hochschule für Technik Rapperswill (HSR). A highly manoeuvrable system capable of speeds up to 180 km/h, the Mobula is ideally suited for long-range missions and engaging moving targets.[969] The Sentinel Catch, developed by SkySec GmbH, is a VTOL drone interceptor that uses a net to capture its target. It is a very light system (1.8 kg) that can reach a speed of 230 km/h and covers a radius of up to 4 km.[970]

Most of the UAV systems procured to the Swiss armed forces are foreign platforms, which would be normal for most countries but is somewhat paradoxical for Switzerland given its national R&D and production capacities in this field.

The Dipper is a unique air-to-sea UAV designed for multi-domain reconnaissance. When flying from the air it can dive into the water, retract its wings and mutate into a UUV.[971] Its main limitation is the short time it can spend in the air, not more than four minutes, which *de facto* limits its range. The AtlantikSolar 2 from ASL and AtlantikSolar is a solar-powered autonomous UAV with extra-long endurance (81 hours at maximum, a world record) and long range.[972] It could become the model for a future HALE or MALE, providing important long endurance capabilities as it can theoretically stay in the sky forever if atmospheric conditions are favourable.[973] The Wingtra One is a VTOL, highly modular and versatile UAV equipped with a high quality camera and modern optronics, making it a well suited system for reconnaissance missions. Furthermore, Wingtra One has an endurance of one hour and a speed of 60km/h, which allows it to cover large distances.[974]

Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019; Interviews.

967 Voliro, https://www.voliro.ethz.ch/home/. (Accessed on 12.04.2023)

968 DroGone – The drone-catching Drone – Official Video, *Youtube*, https://www.youtube.com/watch?v=euXiPlko964&t=51s, 4 July 2020. (Accessed on 12.02.2023)

969 Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/2020*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.: 21.

970 Skysec C-UAS Sentinel Demonstrator, *Youtube*, https://www.youtube.com/watch?v=7NvO9U_NkQ0&t=2s, 23 January 2019. (Accessed on 12.04.2023)

971 Dipper, https://dipper.ethz.ch/index_en.html. (Accessed on 13.04.2023)

972 Solar-powered 81-hour endurance world record flight, *Youtube*, https://www.youtube.com/watch?v=8m4_NpTQn0E, 28 July 2015. (Accessed on 12.04.2023)

973 Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/2020*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.: 21.

974 Wingtra – Fast and accurate survey data every time, https://wingtra.com/. (Accessed on 13.04.2023)

The Elios 2, developed by the start-up Flyability, is a mini-UAV specialised in inspection and navigation missions and in mapping inaccessible sites and infrastructures. Thanks to its excellent thermal and 4k cameras, it can operate in environments without GPS.[975] A new version, Elios 3, has recently been presented, with improved optics and more sophisticated situational awareness.[976] The Flybotix Asio is very similar to the Elios in nature and capabilities, but it can fly longer and its two rotors give it better balance.[977] UAV "Ignis", Latin for "fire", is an autonomous VTOL drone specifically designed to monitor forest fires.[978] It is co-developed by ASL and IGNIS, and could be used for multi-purpose military applications such as logistic support, reconnaissance and C2. Finally, the Astro from Arktis and ETHZ is a multi-purpose mini-drone capable of performing a wide array of tasks, including inspection, reconnaissance and support in crisis situations.[979] This system is very versatile and has been designed to meet the user's needs in terms of payload, camera and speed.

All in all, Switzerland is slowly but surely investing in military drones, having already equipped its armed forces with five systems by early 2023, and developing a dozen more. The Swiss drone market is expected to grow at a significant CAGR of 66.2% in value terms between 2022 and 2025. However, as mentioned above, most of the UAV systems procured for the Swiss armed forces are foreign platforms, which would be normal for most countries but is somewhat paradoxical for Switzerland given its national R&D and production capacities in this field. It is true that Switzerland is making progress in this area, with more than a dozen drone systems under development. But most of these systems are platforms designed primarily for civilian applications – such as firefighting, mapping or reconnaissance – with possible military uses, but these remain mostly in the background. Another element to consider is that today, the air domain is no longer the one that attracts most investments. According to SDRZ experts, the development of drones attracts only about 25% of global investment in military robotics. The other areas, namely water (10-15%) and especially ground (45%), are becoming increasingly important in the field of military robotic systems.[980]

Developments in UGVs and UMSs

The Swiss armed forces do not currently operate UGVs or UMSs. The only plausible exception is the use of a prototype of the Articulated Robotic Manipulator for Numerous Operations also known as "ARMANO", on which the Rescue troops have started to train on, but which is not yet part of the regular equipment available to the armed forces.[981] Six UGVs and two UMSs are currently under development, which confirms the SDRZ experts' predictions of the growing importance of these two types of systems. The Swiss UGV market is projected to grow from USD 6.9 million to USD 17.5 million between 2022 and 2025. This significant increase consists of a growth of 253%, which is much higher than the growth of the drone

[975] Elios 2 - Intuitive indoor inspection drone for confined spaces, *Youtube*, https://www.youtube.com/watch?v=hW1Fn32JBls, 30 April 2019. (Accessed on 12.04.2023)
[976] Elios 3 – Digitalizing the inaccessible, *Youtube,* https://www.flyability.com/elios-3. (Accessed on 13.04.2023)
[977] Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/2020*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.: 21.
[978] ETH students develop new solutions for the future, *ETH Zürich*, https://ethz.ch/en/news-and-events/eth-news/news/2021/07/eth-students-develop-new-solutions-for-the-future.html, 12 July 2021. (Accessed on 12.04.2023)
[979] Astro – Compact Industrial Platform, *Freefly*, https://freeflysystems.com/astro. (Accessed on 13.04.2023)
[980] Interview at the SDRZ, 23 September 2022.
[981] Mit Roboter und Drohnen: Die mögliche Zukunft der Einsatzkräfte, *SRF*, https://www.srf.ch/play/tv/einstein/video/mit-roboter-und-drohnen-die-moegliche-zukunft-der-einsatzkraefte?urn=urn:srf:video:4b1b9ca9-32f2-44f3-a4fd-5ee02b59cbfa, 19 May 2022. (Accessed on 31.03.2023)

market over the same period. In parallel, the UMS market is expected to reach USD 7.4 million in 2025, up from 2.8 million in 2022. This represents a growth of 264%, the largest increase among the three types of systems. While the UMS market is growing rapidly, its significant expansion is also due to the fact that it started from a relatively low level compared to the UAV and UGV markets. The main development is therefore in the UGV sector, which is becoming increasingly competitive and attracting more and more attention from investors and start-ups.

The ANYmal-C, developed by the ETHZ Robotic Systems Laboratory and ANYbotics AG - a university spin-off created to commercialise the technology – is a four-legged humanoid robot designed for industrial applications such as infrastructure inspection and rescue of people in danger. Since the first "ALoF" version in 2009, ANYmal has evolved through 6 successive versions with different lenses and more and more capabilities up to ANYmal-C, with a sharp industrial design, advanced cameras and long life batteries.[982] With a decent speed (3.6 km/h for the legged version and 50km/h for the wheeled one) and a weight of 50 kg, ANYmal is a robust and versatile system capable of carrying out many military tasks: logistics, casualty rescue, breaching, reconnaissance, support, etc.[983] ANYmal's excellence was recognised internationally when it performed well during DARPA's Subterranean Challenge in 2021.[984]

The BoarAI, developed by HSR and Fachhochschule Graubünden is a tracked UGV specifically designed for personnel recovery in dangerous areas.[985] It is able to cope with the approach of explosives or radioactive areas, while ensuring the safety of its operator. The system is partially automated using situational awareness algorithms. The BoarAI was presented and tested during ARCHE 2020 with good results.[986] Ascento is a bipedal robot designed to be agile and to negotiate most types of obstacles, combining the flexibility of legs with the speed of wheels. Jointly managed by ASL and Ascento Robotics, a new version of Ascento PRO has been launched with larger wheels and greater endurance. Ascento can handle heavy payloads and is fully autonomous, being equipped with the latest cameras, LiDAR and sensors. The Ascento PRO is used by the Swiss Federal Railways (SBB) and the security company Securitas to patrol outdoor areas and critical infrastructure.[987]

The UGV ARMANO is the result of a fruitful collaboration between ETHZ, Menzi Muck, Leica Geosystems and Moog.[988] It was originally designed to help solve the problem of unexploded ordnance in the ammunition depot in Mitholz, where more than 3500 tonnes of old explosives and ammunition are still buried.[989] ARMANO is a remotely operated excavator, consisting of an automated excavator machine and a remote tele-operation cockpit, connected by a WLAN connection, cameras and various sensors.[990] ARMANO is being tested by the Swiss armed

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[982] ANYbotics, *ETHZ*, https://rsl.ethz.ch/partnership/spinoff/anybotics.html. (Accessed on 14.03.2023)
[983] Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/2020*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.: 20.
[984] Ackerman, Evan. Inside DARPA's Subterranean Challenge, *IEEE Spectrum*, https://spectrum.ieee.org/darpa-subterranean-challenge-2657170650, 14 March 2022. (Accessed on 14.03.2023)
[985] Roboter für die Katastrophenhilfe: Gespräch mit Mobile-Robotics-Dozent Ulrich Hauser-Ehninger, *Youtube*, https://www.youtube.com/watch?v=8r029q0FLis, 6 january 2023. (Accessed on 13.04.2023)
[986] BoarAI – Projekt auf einen Blick, *Fachhochschule Graubünden*, https://www.fhgr.ch/fh-graubuenden/angewandte-zukunftstechnologien/institut-fuer-photonics-und-robotics-ipr/projekte/boarai/. (Accessed on 13.04.2023)
[987] Securitas tests robot system on SBB site, *startupticker.ch*, https://www.startupticker.ch/en/news/sbb-and-securitas-rely-on-a-two-legged-security-robot, 11 April 2023. (Accessed on 15.04.2023)
[988] Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/20*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.: 20.
[989] Ehemaliges Munitionslager Mitholz, *Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS),* https://www.vbs.admin.ch/de/umwelt/umweltschutz/mitholz.html#ui-collapse-215. (Accessed on 14.04.2023)
[990] Feuertaufe des Forschungsdemonstrators «ARMANO», *armafolio 1/2020*, armasuisse Wissenschaft und Technologie (W+T), 2020.: 31-32.

forces Training unit Genie/Rescue/ABC (Lehrverband Genie/Rettung/ABC - LVBGRABC) at the Competence Centre for Explosive Ordnance Disposal and Mine Clearance (Kompetenzentrum für Kampfmittelbeseitigung und Mineräumung - KAMIR).[991]

The RoBoa is a snake-shaped UGV designed to identify, locate and assist victims after landslides and other natural disasters. Developed by ASL and the start-up RoBoa, the system has already taken part in ARCHE and other demonstrations.[992] Thanks to its unique shape, RoBoa is able to access extremely complex and risky areas, provide first aid and assist people at risk. The Autonomous Rough Terrain Outdoor Robot or "ARTOR" is a six-wheeled UGV developed in a collaboration between ASL, armasuisse and RUAG. Capable of autonomous inertial navigation in a GPS-denied environment, ARTOR is specifically designed for mine-clearance, reconnaissance and support.[993] Its ability to carry a payload of up to 100 kg makes it particularly interesting for military applications. Finally, ARTOR has been designed as a modular and versatile system, easily adaptable to achieve a wide range of missions.[994] Project "Varia" is a UGV programme supported by armasuisse, RUAG and the Fachhochschule Graubünden (FHGR). Little information has been released on this project, but the Swiss armed forces have reportedly provided armasuisse with two type 93/07 Exploration vehicles (Aufklärungsfahrzeuge 93/97) for the development of prototypes.[995]

The Swiss UMS market is relatively small, which is not surprising for a landlocked country. ASL and the start-up Tethys Robotics have developed a UMS system called Scubo 2.0 Marine Advanced Technology Education (MATE). It is a small, highly manoeuvrable underwater drone with 8 rotors.[996] Scubo 2.0 is ideal for mapping underwater areas and conducting forward reconnaissance in dangerous underwater zones. Tethys Robotics has also developed an enhanced version of Scubo, called Proteus, which is the company's first application-oriented system. Proteus is more energy-efficient, more durable and is more robust than Scubo.[997] Proteus is AI-powered, capable of generating live topography models and operating with accuracy to the centimetre.[998] Figure 37 details Switzerland's unmanned and robotic systems in each of the three domains.

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[991] Forschungbroschüre 2022, *armasuisse Wissenschaft und Technologie (W+T),* Eidgenössisches Departement für Verteidigung Bevölkerungsschutz und Sport (VBS), 2022.: 38.
[992] Roboa – Inspecting confined spaces, *ETHZ,* https://roboa.ethz.ch/. (Accessed on 14.04.2023)
[993] ARTOR, *Army Guide*, http://www.army-guide.com/eng/product5582.html. (Accessed on 14.04.2023)
[994] Wie die Schweiz an der Zukunft der Roboter arbeitet, *SRF*, https://www.srf.ch/wissen/technik/wie-die-schweiz-an-der-zukunft-der-roboter-arbeitet, 10 January 2020. (Accessed on 14.04.2023)
[995] Update SDRZ an SAB – Q1 2023, *armasuisse,* Eidgenössisches Department für Verteidigung Bevölkerungschutz und Sport (VBS), 2023.: 1-3.
[996] Lehman, Rebecca. Acht Studenten tauchen ab, *ETHZ*, https://ethz.ch/de/news-und-veranstaltungen/eth-news/news/2019/06/tauchroboter.html, 17 June 2019. (Accessed on 14.04.2023)
[997] Forschungbroschüre 2022*, armasuisse Wissenschaft und Technologie (W+T),* Eidgenössisches Departement für Verteidigung Bevölkerungsschutz und Sport (VBS), 2022.: 41.
[998] Proteus – Prototype V1, *Tethys Robotics*, https://tethys-robotics.ch/index.php/robots/proteus/. (Accessed on 14.04.2023)

Type of robotics	Name	Purpose	Operated by	Manufacturer	Year of acquisition/ latest news	Development Status[999]
Systems used by the Swiss armed forces						
UAV I	Anafi SE	ISR	Army	Parrot	2021	Fielded
UAV I	Black Hornet	Recon.	Army	Prox Dynamics AS	2019	Fielded
UAV I	Indago 3	ISR, C2	Army	Lockheed Martin	2021	Fielded
UAV I	Orbiter 2b	ISTAR	Army	Aeronautics Defense	2014-2018	Fielded
UAV II	Ranger (ADS 95)	ISR	Air Force	RUAG Aerospace	1995	Retired
UAV III	Hermes 900 (ADS 15)	ISTAR, C2	Air Force	Elbit & RUAG	2015	Fielded (2022)
Systems in development with potential military applications						
UAV I	Voliro Hexacopter	ISR	TBD, likely Army	ETHZ ASL, Voliro Airborne Robotics	2017	Development (TRL 4-5)
UAV I	Peregrine	Counter-drone	TBD, likely Army	ETHZ ASL, DroGone	2020	Development (TRL 4-5)
UAV I	Mobula	Counter-drone	TBD, likely Army	HSR Institut für Technik und Kunstoffverarbeitung, Mobula	2019	Development (TRL 4-5)
UAV I	Sentinel Catch	Counter-drone	TBD, likely Army	Skysec GmbH	2019	Development (TRL 5-6)
UAV I	Dipper	Multi-domain ISR (water and air)	TBD, likely Army	ETHZ ASL, Dipper	2019	Development (TRL 4-5)
UAV I	Antlantik-Solar	Long ISR	TBD, likely Army	ETHZ ASL, Atlantik-Solar	2017	Development (TRL 5)
UAV I	Athlas	ISR, landing in difficult terrain	TBD, likely Army	ETHZ Robotic Systems Lab, Athlas	2017	Development (TRL 4-5)
UAV I	Wingtra One & II	ISR, support, VTOL	TBD, likely Army	Wingtra AG	2021	Development (TRL 8-9)
UAV I	Elios 2 & 3	ISR, Navigation highly resistant	TBD, likely Army	Flyability	2022	Development (TRL 8-9)
UAV I	Asio	ISR, inspection	TBD, likely Army	Flybotix SA	2020	Development (TRL 4)
UAV I	Ignis	Rescue	TBD, likely Army	ETHZ ASL, Ignis	2021	Development (TRL 2-3)

[999] Levels of development status according to the Technology Readiness Levels (TRLs) scale from 1 to 9. Levels are the following: (1) Observation and description of functions; (2) Description of a technology's application; (3) Test of a technology's functionality; (4) Test in labour; (5) Test in the environment; (6) Prototype in the environment; (7) Prototype in deployment; (8) Qualified system with proof of functionality with an area of application; (9) Qualified system with proof of functionality in a successful deployment.

UAV I	Voliro T	ISR, inspection	TBD, likely Army	ETHZ ASL, Voliro Airborne Robotics	2022	Development (TRL 7)
UAV I	Astro	ISR, C2, swarming	TBD, likely Army	ETHZ, Arktis, FH Graubünden Auterio	2022	Development (TRL 8)
Swarm	"Swarming munition"	-	TBD	ARDET	2023	Development
UGV	ANYmal-C	Rescue, Inspection, multi-purpose	TBD, likely Army	ETHZ Robotic Systems Lab, ANYbotics AG	2022	Development (TRL 7)
UGV	BoarAI	Rescue, firefighting	TBD, likely Army	HSR	2020	Development (TRL 4-5)
UGV	Ascento 2 & PRO	Recon.	TBD, likely Army	ETHZ ASL, Ascento	2023	Development (TRL 5)
UGV	Armano	Anti-IED, clearing, excavation	Army	ETHZ Robotic Systems Lab, Menzi Muck, Leica Geosystems, Moog	2022	Development (TRL 6)
UGV	RoBoa	Rescue, recon.	TBD, likely Army	ETHZ ASL, RoBoa	2020	Development (TRL 4-5)
UGV	Varia	ISR	TBD, likely Army	Armasuisse, RUAG, FHGR	2023	Development
UGV	Artor	Multi-purpose, CBRN	TBD, likely Army	ETHZ, RUAG		Development (TRL 7)
UUS	Proteus	Support, ISR	TBD, likely Army	ETHZ ASL, Tethys Robotics	2021	Development (TRL 6)
UUS	Scubo 2.0	Explo.	TBD, likely Army	ETHZ ASL, Tethys Robotics	2019	Development (TRL 5-6)

Figure 37 - Military robotic systems fielded, retired and in development with stated or potential military applications in Switzerland.[1000]

[1000] Figure made by the authors. *Sources*: Gettinger, Dan. The Drone Databook, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Military Robotic and Autonomous System (RAS) Market – A Global and Regional Analysis, *BIS Research*, Paseo Padre, California, February 2023.; Chancen nutzen: Forschung und Innovation für die Armee, *armafolio 2/2020*, Schweizer Drohnen-und Robotik-Zentrum (SDRZ), 2020.; Forschungbroschüre 2022, armasuisse Wissenschaft und Technologie (W+T), Eidgenössisches Departement für Verteidigung Bevölkerungsschutz und Sport (VBS), 2022.: 38-41.

Figure 38 - Retrospective of Switzerland's advances in military robotics.[1001]

Switzerland	
Impact of the 4 main factors driving innovation[1002]	1. **Strong**: especially since the Russian invasion of Ukraine 2. **Intermediate**: but growing a support for defence-related innovation 3. **Intermediate**: CH innovation's potential not exploited to its fullest 4. **Strong:** high funding (CHF 103 million in 2019)
Defence-related innovation organisation & governance	**Trio system:** STIB, Armasuisse, Swiss armed forces **STIB diversified**: lots of SMEs and a few large multinationals **Restrictive export policy:** because of neutrality **Incomplete inclusion of the innovative start-ups:** CH's innovation potential not fully exploited
Supranational development projects (non-exhaustive)	**CH not taking part in NATO's DIANA, INF or NIAG** **CH taking part in 6 of EDA's CapTechs**, but not included in other EU security and defence initiatives (PESCO, EDF, EDIDP, PADR, etc.) **CH has multinational defence-related programs through the largest firms** present on its soil: RUAG, Thales, Mowag, etc.
Doctrine development on military robotics	CH doctrine is traditionally oriented towards adaptability and is pragmatic **Integration of military robotic systems is considered as a question of "operating procedures"** **5 main assignments:** (1) Reconnaissance, (2) Protection, (3) Resupply, (4) Evacuation, (5) Preventive maintenance **UAVs: thinking about integration of UAVs is relatively advanced, at all levels of a battalion** and for the three main groups of land forces (artillery, mechanised units, infantry) **UGVs: can improve the force and even replace** certain segments of vehicles
Size of military robotics market (in USD million)	**2022: = 58.2** **2025: = 105.5** **CAGR = 20.17%**

[1001] Figure made by the authors.
[1002] As a reminder, the four indicators are the following: 1) geopolitical environment and threat perception; 2) convergence in political, military and societal support for defence-related innovation; 3) innovation organisation and governance; and 4) investment in defence-related innovation. An explanation and justification of the relevance of these factors can be found on page 77.

Chapter 5: Policy recommendations for Switzerland and conclusion

The analysis of the four drivers of innovation in Switzerland revealed that: (1) the deteriorating European geopolitical context is relatively strongly driving innovation, (2) support for defence issues and defence-related innovation is gaining momentum, (3) the defence innovation ecosystem is evolving despite a non-optimal inclusion of the civilian component, and (4) investment in military innovation is increasing. The case of Switzerland is comparable to other European countries (see Figure 32). Regarding (1), Switzerland is in a similar situation to France and Germany. Its territorial integrity is not directly threatened militarily by Russia's aggression on Ukraine, but its position is politically influenced by the evolving dynamics at the European and global levels. Regarding (2), the case of Switzerland is quite unique in terms of the limitations that the question of neutrality imposes on support for defence-related issues. When it comes to (3), Switzerland has similarities with Germany, particularly regarding the so-called "firewall" between civilian R&D and military applications. In terms of (4), Switzerland sits at the top of the middle European powers – countries such as Sweden and the Netherlands – while remaining behind the largest actors by a significant margin.

Based on these findings, this chapter presents policy recommendations in four areas that armasuisse, the SDRZ and Switzerland at large can examine to improve the Swiss armed forces' ability to develop, produce and use military robotic systems. Following the structure of the study, the four areas of policy recommendations are the following: (1) security & defence policy, (2) institutions governance of procurement and defence innovation, (3) new defence-related “ethos” and, (4) military doctrines, standards, norms and procedures. In sum, this chapter presents ten policy recommendations in the four abovementioned areas. These should be considered as providing orientation and broad guidance rather than detailed suggestions on the substance and their implementation. Figure 38 below lists the ten policy recommendations divided into four policy areas.

The final part of this chapter concludes the study by presenting a relevant summary of the five chapters. In this summary, particular attention is paid to Switzerland's strengths and weaknesses, especially in relation to the other case studies. It considers the main technological developments as well as the political dynamics and competition discussed in chapters 1 to 3. A final section identifies a number of issues related to military robotic systems that need to be addressed in the near future to provide armasuisse, the SDRZ and Switzerland at large with technologically advanced and effective armed forces.

Policy area	*Recommendations*
Security & defence policy	1. Enhance the collaboration of Swiss innovation bodies with existing and new EU, NATO and other multilateral instruments.
Institutions, governance of procurement and defence innovation	2. Review and consider the adaptation of the structure and orientation of SDRZ in order to fulfil the quick procurement needs of the Swiss armed forces.
	3. Encourage innovation by using RUAG MRO as a quasi-in-house procurement organisation for the Swiss armed forces.
	4. Ensure that the SDRZ works more closely with the test units of the Swiss armed forces.
New defence-related innovation “ethos”	5. Change the culture of innovation: embrace risk, accept failure and encourage Concept Development and Experimentation (CD&E).
	6. Support the ongoing societal debate and inform the public about the role of defence and defence-related innovation.
	7. Increase involvement of civilian research and industry in the development of technologies and systems for the Swiss armed forces.
Military doctrines, standards, norms and procedures	8. Develop the understanding and operationalisation of the Swiss principles for the responsible use of military robotic systems.
	9. In the medium/long term, deepen the doctrinal thinking on the integration of military robotic systems into the armed forces and identify options for their use in combat, combat support and suppression operations.
	10. Search and identify which standards, norms, and formats are to be implemented in the acquisition and use of military robotic systems for the Swiss armed forces.

Figure 39 – The four domains of policy recommendation.

Security and defence policy

Recommendation 1: *Enhance the collaboration of Swiss innovation bodies with existing and new EU, NATO and other multilateral instruments.*

General political framework

As the international order becomes increasingly polarised and strategic competition intensifies, Switzerland should seek to strengthen cooperation with NATO and the EU in the areas of force integration (interoperability), defence innovation and defence industrial policy. This can be done without Switzerland formally joining these institutions, but through proactive and targeted political signalling and engagement.[1003] This would be promoted by the following measures:

- A proactive stance adopted by the relevant actors at their respective levels (political, military, industrial) would encourage closer cooperation between Switzerland, the EU, NATO and current or upcoming multilateral initiatives. This would demonstrate that closer cooperation in security and defence policy can be achieved while respecting Switzerland's neutrality – both politically and legally. Switzerland can communicate its willingness to cooperate and present itself as a reliable and interesting actor in defence and military affairs.

- Making use of the recent momentum in the Euro-Atlantic architecture of innovation for security and defence innovation, which has led to an increased efforts for cooperation between EU and NATO instruments, which could develop towards a certain degree of complementarity and burden sharing.

NATO

NATO's raison d'être is reinforced by the current war in Ukraine, and the alliance is currently developing tools to align its member states' policies on defence-related innovation, defence industrial policy and defence investment (INF, DIANA, NATO Industrial Advisory Group (NIAG), NATO Joint Analysis & Lessons Learned Centre (JALLC)). Switzerland has much to gain from a closer relationship with NATO in these areas. Similarly, Switzerland's cutting-edge innovation capabilities could be of interest to NATO. There is potential for win-win cooperation here, and Switzerland could take the initiative to make the most of this opportunity.[1004] To do so, the relevant actors may:

- Consider strengthening NATO's Individual Partnership Programme for Cooperation (IPCP) under the PfP at the political level, with the aim of providing a basis for Switzerland's further engagement in a wide range of NATO activities and developing possible opportunities in the field of innovation.

- Evaluate the possibility of becoming an Enhanced Opportunity Partner (EOP), which would offer benefits to Switzerland and whose status would be decided on an ad hoc

[1003] “Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung, *Center for Security Studies (CSS)*, CSS Briefing-Papier, 2022.: 4.
[1004] Larsen, Henrik. “Die Schweiz und die NATO: neue Konvergenz.” *Center for Security Studies (CSS*), ETH Zurich, 11 December 2019.: 69.

basis, and which could possibly offer privileged access to the NATO STO[1005], strengthening cooperation in defence-related innovation. Seek to participate in selected DIANA activities and special facilities, as Switzerland's contribution would likely be welcomed given its innovation potential.[1006]

- Contribute to NATO's anticipatory and conceptual monitoring and thinking on EDTs (especially robotics and AI), their future use, and potential implications.

European Union

Similarly, EU initiatives are multiplying and gradually providing it with tools to develop defence and innovation projects. Unfortunately for Switzerland, most of these tools are reserved for member states, such as EDIDP and PADR. Since Switzerland is involved in six EDA "CapTechs", it should try to participate in more multinational projects. Similarly, HEDI is an initiative that aims to bring together academia, the defence industry and start-ups, and Switzerland would greatly benefit from joining it. Overall, the relevant actors at their respective levels may:

- Increase their participation in the EDA's "CapTechs" projects – particularly on Key Strategic Areas (KSA) and autonomous and robotic systems – as it is one of the few institutions open to non-MS.[1007]

- Evaluate the possibility for the industry to participate – possibly under the umbrella of a Swiss industry sector association (i.e. Swiss ASD and Groupement Romand Pour le Matériel de défense et de sécurité (GRPM))[1008] – in projects financed by the EDF and, in this respect, strengthen institutional contacts with DG DEFIS.[1009]

- Consider contributing to HEDI, which is new and could therefore provide an opportunity for Switzerland to get its foot in the door of EU-wide R&D projects in the field of EDT.[1010]

Other multilateral instruments

Switzerland may consider the possibility of deepening cooperation with other multilateral instruments of defence-related innovation and force generation. These include the Multinational Capability Development Campaign (MCDC). MCDC *"(…) is an initiative led by the United States Joint Staff J-7 that partners with 23 countries and international organizations (IGO) designed to develop and assess non-materiel (non-weaponry) force development solutions."*[1011] The MCDC is an important institution because it has developed a working

[1005] Lété, Bruno and Basagni, Laura. NATO's Enhanced Opportunities Partners, *German Marschall Fund of the US*, https://www.gmfus.org/news/natos-enhanced-opportunities-partners, (Accessed on 01.06.2023).
[1006] "Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung, *Center for Security Studies (CSS)*, CSS Briefing-Papier, 2022.: 9.
[1007] Interview with EDA officials, 29 March 2023.
[1008] For further information, refer to: Swiss ASD, https://www.swissmem.ch/de/produkte-dienstleistungen/netzwerke/industriesektoren/swiss-asd.html, (Accessed on 10.10.2023); GRPM, https://grpm.ch/, (Accessed on 11.10.2023)
[1009] DG DEFIS is the European Commission department responsible for strengthening the competitiveness and innovation of the European defence industry by ensuring the evolution of a stronger and more robust European defence technological and industrial base.
[1010] "Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung, *Center for Security Studies (CSS)*, CSS Briefing-Papier, 2022.: 13.
[1011] Multinational Capability Development Campaign (MCDC) – Closing the Gaps in Multinational Operation, 2019.: 1.

method for identifying capability gaps and finding solutions collaboratively through multinational efforts and interoperable solutions. Specifically, the relevant actors at their respective levels may:

- Try to be more present in MCDC's Executive Steering Committee (ESG) that conducts relevant work in international force development activities, centres of research and development, Concept Development and Experimentation (CD&E).

- Move closer to the project "Military Uses of Artificial Intelligence, Automation, and Robotics (MUAAR)" co-led by NATO STO and the US, which identifies the potential of AI and robotics in military functional areas.[1012]

- Overall, the SDRZ should seek enhanced connection, exchange, dialogue and cooperation with international relevant actors. This could be done through the set-up of an annual forum, for example.

[1012] *Ibid.*: 7.

Institutions, governance of procurement and defence innovation

Recommendation 2: *Review and consider the adaptation of the structure and orientation of SDRZ to fulfil the quick procurement needs of the Swiss armed forces.*

The main objective of the SDRZ is to meet the research and operational requirements of the Swiss armed forces in the field of UAVs and robotics. While the SDRZ has been successful in testing robots and UAVs, evaluating their performance and supporting new projects, its current institutional framework does not provide sufficient freedom to fulfil its primary mission. As a result, a review of the organisation's institutional structure and basic operations is recommended, including an assessment of its institutional and/or legal form. A theme that emerged from many discussions with representatives from other countries is the need for an institution to oversee innovation and R&D in robotics that is able to be flexible in the procurement process.Therefore, it is recommended to:

- Consider transforming the SDRZ's legal status as an administrative unit that is more appropriate for allowing institutional and organisational flexibility and the ability to engage in short- and medium-term procurement processes. In this regard, the establishment of another institutional form – for example a foundation under Swiss law – should be explored.

- Consider the establishment of links to other bodies within or outside the Swiss administration, such as the new DDPS State Secretariat, the new Innovation Unit of the armed forces and/or the Swiss Innovation Forces (SIF) which can enhance funding and impact of the SDRZ’s work.

This would notably mean, for SDRZ and armasuisse:

- Gains in terms of ability to raise funds and support R&D projects, given that Swiss law allows this for non-profit organisations (Civil Code Art. 86a and Federal Law of 14 December 1990 on direct federal taxation, Art. 56).

- An easier use of the right of exception to the obligation of opening bids to the public market and transparent competition in case of “national defence issues”, similar to European Union members, with the Treaty on the Functioning of the European Union (TFEU), Art. 346 and EU Directive 2009/81 EC, Art.4; 5, al.1; 10; 20.

***Recommendation 3**: Encourage innovation by using RUAG MRO as a quasi-in-house procurement organisation for the Swiss armed forces.*[1013]

For armasuisse, the SDRZ and the Swiss armed forces, the fact that the Confederation can legally use RUAG MRO as a quasi-in-house procurement agency without having to comply with public procurement law is advantageous, because it allows them to:

1) Facilitate and speed up the procurement procedures in contrast to federal administrative offices and institutions.

2) Carry out facilitated (quasi-in-house) procurement, with the positive effect of stimulating innovation and speeding it up.

With regard to Point 1), the procedures for awarding contracts under public procurement legislation are long and complicated as they consist of a tendering procedure, a call for competition, an award decision and possible appeals, etc.[1014] The possibility of using RUAG MRO as a quasi-in-house procurement organisation allows armasuisse and SDRZ to make some acquisitions more *flexibly*, *quickly* and *diversely* without having to observe all the aspects of the public procurement regulations.

- In terms of *flexibility*: RUAG MRO can be used as a quasi-in-house procurement body according to specific needs and timeframes. This does not mean that armasuisse and SDRZ have to use RUAG MRO as a quasi-internal procurement organisation for every acquisition.

- In terms of *speed:* the possibility of awarding contracts through RUAG MRO avoids certain cumbersome and time-consuming administrative procedures associated with public procurement law. Armasuisse and SDRZ would thus be able to acquire technologies and systems much more quickly and easily. The Swiss armed forces, in turn, would benefit from being able to acquire and test equipment and systems more quickly.

- In terms of *diversity*: the increased flexibility and speed of the procurement process means that armasuisse and SDRZ do not have to put all their eggs in one basket, but can procure different systems at the same time, allowing for testing and corrections along the way.

- The approach should have a twofold objective: (a) to implement a tailored acquisition approach (short-, medium-term and for evolutionary, revolutionary technologies); (b) to better involve the industrial base, in particular by taking into account the potential impact on civil and commercial industry.[1015]

[1013] The legal rationale proving that the Confederation can use RUAG MRO as a quasi-in-house procurement body can be found in the Appendix.
[1014] Loi fédérale sur les marchés publics (LMP), *Conseil fédéral et administration fédérale*, 21 Juin 2019, 172.056.1.
[1015] Wong, Jonathan P., et al. *Improving Defense Acquisition: Insights from Three Decades of RAND Research*. Santa Monica, CA: *RAND Corporation*, 2022.: 29.

Regarding Point 2), the possibility of using RUAG MRO as a quasi-internal procurement organisation would make it possible to increase the support and financial assistance to start-ups and other structures at the forefront of innovation in high-tech areas, such as EDTs. It would help innovators and start-ups in two ways: in the *early phase* of R&D projects, namely at early TRLs (2-5); and during the *transition to a prototype,* at TRLs 7-8.

- The *early TRL (2-5)* – from basic technology research to technology development – are always the most difficult part for innovators, requiring intensive research and financial effort, with no certainty that the project will bear fruit and lead to a marketable product. As a result, many innovators and start-ups are unable to take the risk of committing to early-stage R&D programmes, or lack the financial resources to do so and to develop a demonstrator. This issue was raised several times during the interviews, particularly in Norway with FFI and in the UK with FCG.[1016] The possibility of using RUAG MRO as a quasi-in-house procurement organisation would go some way to solving this problem because by avoiding procurement processes involving competition between different systems from different innovators, RUAG MRO could commit before and at the beginning of the R&D process to support a particular start-up and buy its product. This could encourage greater innovation and speed up the process of advanced technologies.

- The *transition phase to the prototype (TRL 7-8)* is also particularly challenging, as it bridges the gap between the ideation phase and a phase in which a system is placed in a real environment and is therefore confronted with numerous obstacles that were not foreseen beforehand. This phase is essential because it allows the innovator to better identify the limits and capabilities of his product. It could also be described as a “trial by fire”, because if a system turns out to be far from the performance assumed in the previous phases, it may have to go back to the drawing board. In this context too, the use of RUAG MRO as a quasi-internal procurement organisation would improve the support and monitoring of start-ups and innovators, facilitate the transition to prototypes and act as a link between innovators, the defence industry and the federal administration. This is one of RUAG MRO's three core tasks of a "service provider for innovation and technology".[1017]

[1016] Interview at the Norwegian Defence Research Establishment (FFI), 28 April 2023.
[1017] RUAG Innovation Forum 2021 – Presentation, 2021.: 3.

Recommendation 4: *Ensure that the SDRZ works more closely with the test units of the Swiss armed forces.*

The *raison d'être* of the SDRZ is to provide a platform for testing and evaluating unmanned systems and robots for the Swiss armed forces, with a view to their potential use in defence and security.[1018] However, the SDRZ faces administrative or legal constraints when it comes to testing armed military robots and EDTs in the defence sector. In addition, the SDRZ's interactions with the existing Swiss armed forces test centres (e.g., in Walenstadt) could be more extensive in order to allow for real monitoring and sustainable cooperation in the long term. In addition, closer cooperation with foreign test centres and similar organisations should be considered. To address these issues, armasuisse and SDRZ may consider:

1) Testing systems in the full spectrum of military operations.

2) Strengthening the cooperation with the Swiss armed forces in general and their test centres in particular and fostering a community of practice in military robotics within the STIB.

3) Strengthening cooperation with foreign test agencies and similar organisations.

With regard to Point 1), armasuisse and the SDRZ should conduct trials of robotic and autonomous systems in the full spectrum of military operations – including high-intensity operations – in order to prepare the armed forces for their use by potential enemies or by themselves in the event of a major crisis. The conventional threats to Switzerland's national security have increased over the last decade andit is necessary to take appropriate measures in this context. To this respect, the decision not to equip the ADS 15 UAVs with the provision to upgrade them with strike capabilities can be questioned, as the possibility of having at least this option would have proved to be useful today for training purposes and for strengthening the deterrence posture of the Swiss armed forces.[1019]

The SDRZ declares in a document that: *"Switzerland does not intend to procure fully autonomous weapon systems. However, it has an interest in exploiting the potential of advances in artificial intelligence and greater autonomy in weapon systems for defence capabilities."*[1020] This in turn means that armasuisse and the SDRZ should take steps to test equipment across the entire spectrum of military operations, from loitering ammunition to micro-UAVs and armed UGVs. Furthermore, the testing of robotic and autonomous systems for potential defensive use would in no way contradict Switzerland's policy of supporting binding international commitments to reduce and limit the proliferation and use of LAWS.[1021] Since there are no rules prohibiting such tests, and since the main restrictions to date have been self-imposed, it is necessary to go beyond them and test these systems. Armasuisse and SDRZ may:

- Seek the competencies and legal basis to test military applications of robotics and related technologies.

[1018] Schweizer Drohnen- und Robotik-Zentrum, *armasuisse W+T*, Eidgenössisches Department für Verteidigung, Bevölkerungschutz und Sport (VBS), 2017.: 1.
[1019] Luftverteidigung der Zukunft, *Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS)*, 2017.: 48-49.
[1020] Autonome Waffensysteme (AWS) – Pocketcard, SDRZ, *armasuisse W+T*, Eidgenössisches Department für Verteidigung, Bevölkerungschutz und Sport (VBS).: 3. Translation by authors.
[1021] Stratégie de maîtrise des armements et de désarmement 2022–2025, *Département Fédéral des Affaires Etrangères (DFAE)*, Confédération Suisse, 2022. : 27.

- Define new procedures to operate more test ranges and training facilities for UAVs and to ensure that system evaluations are conducted under real/field conditions.[1022]

- Test robotic systems across the full spectrum of military operations – including high-intensity operations – to ensure that they can be used to the benefit of the Swiss armed forces in real-world operations.

Regarding Point 2), the SDRZ already has access to several test and training facilities, such as Wangen an der Aare (LVb G/Rttg/ABC) where ARCHE is held on a regular basis, and to other DDPS facilities. In addition, the SDRZ is setting up the Security Robotics programme with the ETHZ in order to gain access to its infrastructure.[1023] These efforts are noteworthy and point in the right direction, but they do not fully meet the SDRZ's objective of understanding how to put technology in the hands of the soldiers. Armasuisse and SDRZ may:

- Test robotic systems in cooperatrion with and through specially selected, existing units, such as the Special Forces Command.

- Consider the creation of a kind of "battle lab" with the specific task of familiarising members of the armed forces with the military applications of new technologies, in particular military robotics.

- Support the Swiss armed forces to create or adapt an operational unit (for example the LVb G/Rttg/ABC) to host the "battle lab" and to ensure proximity to the end-user.

With regard to Point 3), the SDRZ could seek to mirror the way other countries test military robotics and could work with these foreign actors. The UK, for example, has set up a battle lab in 2022 to help drive innovation in the armed forces and give end users direct access to the technology.[1024] Similarly, France currently has several of such test facilities: the AID's Défense Lab and the Battle Lab Terre, which is specifically dedicated to land force applications.[1025] The Netherlands, which has directly created a specialised unit within one of its brigades (RAS Unit in the 13th Light Brigade) to use the technology and develop doctrinal concepts, could also be an interesting concept for Switzerland.[1026] The objective of the Dutch RAS unit is to develop Concept Development & Experimentation (CD&E), paving the way for the operational use of military robotics directly for the end-user. Armasuisse and SDRZ may:

- Test robotic systems in cooperation with foreign armed forces and their test units and specialised agencies.

- Participate in CD&E with foreign armed forces and their test units.

[1022] Interview at the SDRZ, 23 September 2022.
[1023] Interview at the SDRZ, 23 September 2022.
[1024] New Defence BattleLab to drive innovation, *Gov.uk*, https://www.gov.uk/government/news/new-defence-battlelab-to-drive-innovation, 18 May 2022. (Accessed on 09.06.2023)
[1025] France inaugurates Battle Lab Terre, *Shepherd*, https://www.shephardmedia.com/news/defence-notes/france-inaugurates-battle-lab-terre/, 8 January 2021. (Accessed on 09.06.2023)
[1026] Rheinmetall robotic vehicle joins Dutch Army experimentation program, *DefBrief,* https://defbrief.com/2020/11/10/rheinmetall-robotic-vehicle-joins-dutch-army-experimentation-program/, 10 November 2020. (Accessed on 09.06.2023)

New defence-related innovation "ethos"

***Recommendation 5**: Change the culture of innovation: embrace risk, accept failure and encourage Concept Development and Experimentation (CD&E).*

Innovation is about creating new things and new ways of thinking, which naturally involves the risk of failure. Indeed, the process of innovation necessarily involves failure, learning through trial and error, and successive adaptation.[1027] This is particularly true for innovation in EDT, which requires long and very costly R&D programmes. Consequently, innovation in EDT requires stable, long-term financial commitments to ensure the continuity of projects in the medium and long term. When applied to the military sector, the notion of Concept Development and Experimentation (CD&E) is particularly appropriate, as it allows the structure and methods of experimental science to be applied to the development of breakthrough military technologies, in particular by reducing costs and maximising upstream financial resources.[1028] In order to initiate this change in the innovation culture, armasuisse, the SDRZ and the Swiss armed forces may:

1) Set up a kind of defence-related innovation fund.

2) Provide training and education as well as implement CD&E to encourage bottom-up innovation.

Regarding Point 1), many countries have established mechanisms to target and support start-ups and innovators developing dual-use technologies with potential military applications. This is the case in the UK with DASA, which is an accelerator that provides funding and technical support to SMEs and start-ups, through instruments such as the Defence Innovation Initiative (DII) and thematic competitions. Between 2021 and 2022, DASA accelerated 843 projects and provided USD 170 million in funding.[1029] Another very interesting example for armasuisse and SDRZ is France, where AID has created the Fonds Innovation Défense (FID) in 2021. This fund is a complementary investment instrument designed to incubate and accelerate the development of technologies with potential military applications. The focus is on cutting-edge technologies and national preference. The fund has a budget of USD 216 million.[1030] Importantly, the FID has created the *Projet DECLIC "(…) designed to disseminate and encourage a culture of innovation within the defence community."*[1031] The aim of this project is to raise the awareness of the defence community and the general public on the issues surrounding innovation in the military sector and to strengthen the societal and technical support for this innovation. The NATO INF is another example of the creation of an innovation

[1027] Coldwell, Chris. Why Failure Is A Necessary Part of The Innovation Process, *Forbes*, https://www.forbes.com/sites/forbesbusinesscouncil/2022/11/04/why-failure-is-a-necessary-part-of-the-innovation-process/?sh=79775ba63ff7, 4 November 2022. (Accessed on 12.06.2022)
[1028] Pavlov, Nikolay. "NATO's Concept Development and Experimentation Approach in the EU's Common Security and Defence Policy? – An Institutional Isomorphism Perspective." *Defence Studies* 22, No. 2, 2022.: 211–30.
[1029] Innovation for a Safer Future DASA Strategy 2021-2024, *Defence and Security Accelerator (DASA)*, Ministry of Defence, 2021.: 4.
[1030] Innovation de défense – Bilan d'activités 2022, *Ministère des Armées*, République Française, 2022.: 64.
[1031] *Ibid.*: 65.

fund that allows smaller countries to collectively participate in a supranational venture capital fund.[1032]

Switzerland may try to replicate these practices, not necessarily by creating a new structure, but possibly by modifying some of the existing instruments in this area. Such efforts would include:

- Rethinking the way the credits for "Project studies, testing and preparation of purchases" credits (*Études de projets, essais et préparatifs d'achats* – EEP) which is an investment deposit totalling USD 150 million in 2023, are allocated by creating a specific envelope for R&D only. It supports development, prototyping and testing, as well as science and technology.[1033] Trying to allocate more funds to this instrument for innovation, technology and a wider involvement of civil start-ups would certainly allow for a more efficient use of resources.

- Considering the creation of a dedicated defence innovation fund, to provide direct support to start-ups to develop potential dual-use applications and to attract civilian applications to the military sector.[1034] This fund could also help to change the societal debate on the role of innovation in defence (as the DECLIC project is doing in France).

For Point 2), the notion of CD&E is a very relevant concept *"(…) enabling the structured development of creation and innovation ideas into viable solutions for capability development."*[1035] It is a concept that emerged within the US DoD in the 1990s as a key element in improving military capabilities, defence planning and force modernisation.[1036] CD&E would be useful for Switzerland in the process of changing the way defence-related innovation is conducted. Overall, CD&E enables a more agile and flexible institutional culture and opens the military domain to entrepreneurial ways of thinking. Therefore, armasuisse and the SDRZ may:

- Organise workshops (in the spirit of DEFTECH Days) and working groups at an early stage in the definition of new capability requirements, bringing together all stakeholders, from the legal team to acquisition support, including end users and staff officers, to draft the most appropriate requirements.[1037]

- Accept the risk inherent in innovation activity and in the idea that risk-taking should not be penalised, especially if it leads to failure.[1038]

[1032] Estonia invests 30 million euros in the NATO Innovation Fund through SmartCap, *Smart Cap*, https://smartcap.ee/estonia-invests-30-million-euros-in-the-nato-innovation-fund-through-smartcap/#:~:text=Estonia%20will%20invest%2030%20million%20euros%20in%20NATO,technologies%20with%20dual%2C%20i.e.%20civilian%20and%20military%20use., 2 March 2023. (Accessed on 13.06.2023)

[1033] Message sur l'Armée 2023, Armée Suisse, *Département de la Défense, de la Protection de la population et des Sports (DDPS)*, 2023.: 16.

[1034] Point presse du 08/06 : l'innovation de défense, Ministère des Armées, *YouTube*, https://www.youtube.com/watch?v=i6WnzS2lJVc, 8 June 2023. (Accessed on 13.06.2023)

[1035] Pavlov, Nikolay. "NATO's Concept Development and Experimentation Approach in the EU's Common Security and Defence Policy? – An Institutional Isomorphism Perspective." *Defence Studies* 22, No. 2, 2022.: 215.

[1036] Birkler, John. et al. "Gaining New Military Capability. An Experiment in Concept Development". *RAND Corporation*, 1998.

[1037] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS),* 2022.: 17.

[1038] Anthony, Scott et al. Breaking Down the Barriers to Innovation, *Harvard Business Review*, https://hbr.org/2019/11/breaking-down-the-barriers-to-innovation, November-December 2019. (Accessed on 14.06.2023)

***Recommendation 6**: Support the ongoing societal debate and inform the population in the role of defence and defence-related innovation.*

Switzerland is in a paradoxical position where the public has a somewhat restricted interest on military matters but also demonstrates a strong commitment to national defence. This is the result of more than thirty years of "peace dividends" and "facilitated neutrality", made possible thanks to Switzerland's geographical position and a stable international context. This tendency is reflected in the so-called "firewall" between civilian innovation and military applications that exists in many countries but is particularly pronounced in Switzerland.[1039] On the other hand, the need to maintain armed forces capable of defending the country is not questioned in Switzerland. According to a 2022 study, 75% of respondents indicated that they considered the Swiss armed forces to be "absolutely necessary/mostly necessary" to ensure the country's safety.[1040] A similar observation highlights that most Swiss citizens support the means to achieve this end, as 70% agreed with the formula "Switzerland should maintain a fully equipped armed forces."[1041] In many ways, this paradox needs to be addressed at the national level in the form of a debate on the future of Swiss security and defence policy.

To this end, armasuisse and the SDRZ can also contribute to actively informing the public about the requirements of Swiss military autonomy in a deteriorating geopolitical context, especially with regard to capabilities, the defence industry and defence-related innovation. Armasuisse and the SDRZ must make themselves known to the Swiss public and explain their objectives and values. In addition, they should emphasise the importance of having a sovereign national defence industry that is *"(…) in a position to ensure that the technology and industrial capabilities that are central to the Armed Forces and other federal institutions of national security are available in Switzerland with the required capacities."*[1042] These efforts could include initiatives such as:

- The organisation of events such as conferences, workshops and seminars with experts, academics, representatives of the administration and the armed forces to familiarise the participants and the public with these issues (for example initiatives in the spirit of the DEFTECH Days, or the exercise CoHoMa in France).[1043]

- The publication of information on the current situation of the Swiss defence industry and the (operational) requirements of the Swiss armed forces. An increased presence in the national media would also be relevant and beneficial.

- Actively contributing to keep the public aware the *raison d'être* of the Swiss armed forces is to defend the territorial integrity and the population of the country. To achieve this goal, armasuisse and the SDRZ can contribute to in informing on the relevance of defence -innovation and technology and thus the role of the Swiss armed forces in the current security context.

[1039] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.

[1040] Tresch, Tibor Szvircsev et al. "Nachbefragung der Studie «Sicherheit 2022» aufgrund des Krieges in der Ukraine Aussen-, Sicherheits- und Verteidigungspolitische Meinungsbildung im Trend", *Militärakademie (MILAK), Center for Security Studies (CSS)*, ETH Zürich, 2022.: 181.

[1041] *Ibid.:* 185.

[1042] Security-Relevant Technology and Industry Base – Infographic, *armasuisse*, Département de la Défense, de la Protection de la population et des Sports (DDPS), 2021.

[1043] CoHoMa II : quand l'homme et le robot « s'emparent de l'objectif », *Ministère des Armées*, https://www.defense.gouv.fr/actualites/cohoma-ii-quand-lhomme-robot-semparent-lobjectif, 14 Avril 2023. (Accessed on 22.06.2023)

***Recommendation 7**: Increase involvement of civilian research and industry in the development of technologies and systems for the Swiss armed forces.*

The link between the defence industry and the civilian industry is key to ensuring that the Swiss armed forces receive high quality and reliable equipment. However, some civilian players with highly innovative systems and potential seem not to be interested in participating in projects involving the development of systems with potential military applications (the so-called "firewall"). This results in a major *manque à gagner* for Switzerland, as there are many SMEs and start-ups with good ideas that are not being exploited to their full potential. There are two main possible reasons for this: (1) developers seem not to be interested in contributing to the development of systems with potential military applications, and (2) these start-ups and companies are not listed in armasuisse's "Security-relevant technologies".[1044] Armasuisse and the SDRZ can contribute to address both issues by making the civil industry more aware of the significance of their involvement in the development and production of systems for the Swiss armed forces. This would include:

- Participation in informing of civil industrial players about the relevance of the STIB and its link to national defence, in collaboration with the Swiss aeronautics, security and defence industry sector.

- Reinforce the process of mutual understanding between the defence sector and the STIB players by organising appropriate activities and events.[1045]

- Seek to establish a community of practice on military robotics within the STIB. This could be done with the support of the GCSP, Swissmem and/or other organisations.

- Stepping up efforts to identify and monitor (see the example of France and the AID's "veille technologique active")[1046] civilian companies and emerging technologies that could possibly be part of the STIB and take appropriate measures to support them.

- Acquisition of civil technologies and systems to test them for military purposes.

[1044] Security-relevant technologies*, armasuisse*, Swiss Confederation, February 2021.
[1045] Plan d'action sur les synergies : entre les industries civile, spatiale et de la défense, *Commission Européenne*, 2021.: 8.
[1046] Document de Référence de l'Orientation de l'Innovation de Défense, *Ministère des Armées*, Juillet 2022.: 27.

Military doctrines, standards, norms and procedures

Recommendation 8*: Develop the understanding and operationalisation of the Swiss principles for the responsible use of military robotic systems.*

The integration and use of robotic systems within the armed forces is currently considered as a matter of "operational procedure" (Einsatzverfahren) or "principles of engagement" (Grundsätzen), which indicates that the Swiss armed forces have not yet given sufficient thought to this issue.[1047] Additional thinking should lead to the development and establishment of guidelines and principles of use, that will enable the armed forces – and especially the- to develop army to design doctrinal concepts that can be implemented in the field.

Switzerland's "Arms Control Strategy 2022-2025" and the Swiss armed forces' guiding principles have incorporated ethical principles, namely (1) legality, (2) responsibility, (3) reliability and, (4) agility.[1048] In October 2021, NATO published its "Principles of Responsible Use of Artificial Intelligence in Defence", which consists of five main guidelines[1049]: (1) lawfulness, (2) responsibility and accountability, (3) explainability and traceability, (4) reliability and, (5) governability. NATO is now working to operationalise the principles.

These principles must be consistent with international rules and state commitments.[1050] The GCSP is currently working on the meaning and operationalisation of ethical principles for AI.

To this end, armasuisse, the SDRZ and the Swiss armed forces may:

- Identify how these ethical principles could be implemented at the tactical and technical levels. This can build on the work of NATO, the GCSP and other actors. In addition, further research and workshops can help to improve the knowledge base and access to international expertise in this area.

- Establish an incremental – step-by-step, building-block – method for developing ethical doctrinal concepts for the use and integration of military robotics at all levels of command, as demonstrated by the Dutch case.

- Use existing expertise and these ethical principles and standards to develop and test technologies and processes. Ensure adaptability in the doctrine development process by encouraging rapid start-ups and short-cycle experimentation, investing in projects in different directions and adopting an entrepreneurial mindset that allows for unconventional solutions free from cumbersome bureaucratic processes.[1051]

[1047] Interview with the Chief of Military Doctrine in the field of Enterprise Development Defence (Militärdoktrin im Bereich Unternehmensentwicklung Verteidigung), Swiss armed forces, 6 March 2023.
[1048] Strategie Rüstungskontrolle und Abrüstung 2022–2025, Schweizerische Eidgenossenschaft, *Eidgenössisches Department fur Auswärtige Angelegenheiten (EDA)*, 2022.: 42. (Anhang 3)
[1049] An Artificial Intelligence Strategy for NATO, *NATO*, https://www.nato.int/docu/review/articles/2021/10/25/an-artificial-intelligence-strategy-for-nato/index.html, 25 October 2021. (Accessed on 15.06.2023)
[1050] Vestner, Tobias. Responsible AI Symposium – The Nexus Between Responsible Military AI and International Law, *Lieber Institute*, West Point Academy, https://lieber.westpoint.edu/nexus-between-responsible-military-ai-international-law/, 17 November 2022. (Accessed on 15.06.2023)
[1051] Rademaker, Michel and Mevissen, Sjoerd. "Robotic and Autonomous Systems: From design to development and use in military operations", *The Hague Centre for Strategic Studies (HCSS),* November 2022.: 19-20.

***Recommendation 9**: In the medium/long term, deepen the doctrinal thinking on the integration of military robotic systems into the armed forces and identify options for their use in combat, combat support and support operations.*

The Swiss armed forces, and in particular its military doctrine branch, should define operational guidelines for the use of military robotics. This starts with answering a very simple question: why do the armed forces want to use military robotics? More detailed consideration needs to be given to the tasks these systems should be assigned, how they should be integrated with the human component and how they should be used in an operational context. In the medium and long term, it will be necessary to deepen doctrinal thinking in order to integrate military robotic systems into the Swiss armed forces and to identify options for their use in combat, combat support and support operations. For this purpose, armasuisse and the SDRZ may:

1) Link concept development to field experimentation (CD&E) and, where possible, to technology and systems development.

2) Demonstrate inventiveness in the development of doctrinal concepts, in particular by using a kind of "Red Team".

With regards to Point 1), several of the interviewees stressed the importance of short-cycle experimentation processes to enable the emergence and continuous improvement of user concepts.[1052] This element was particularly relevant in the case of the Dutch RAS Unit, where field experiments are continuously monitored, analysed and measured to enable military robotic systems to be used more in relation to the soldiers' needs, in clear scenarios and with pre-defined tasks.[1053] In this context, CD&E should be used extensively as a working method. In particular, armasuisse and the SDRZ can try to support the Swiss armed forces in clarifying the following points:

- Articulate the needs and implications of the gradual integration of robotic assets in human units and, in the longer term, the complete replacement of certain tasks entirely by robots.[1054] The issue of man-machine synergies (MUM-T) is also noteworthy and requires further consideration.[1055]

- Where appropriate, the work carried out by other armies, in particular the French land forces, which have identified a number of tasks for unmanned systems, should be replicated and adapted:[1056]
    - *Defensive tasks:* (a) protecting a logistical infrastructure, (b) patroling and defending the rear of large units (divisions, brigades), and (c) monitoring a gap area.

[1052] Interview the Future Capability Group (FCG), UK Ministry of Defence, 26 April 2023.
[1053] Interview with the Royal Netherlands Army, 13 Light Brigade's Robotic and Autonomous Systems (RAS) Unit, 19 June 2023.
[1054] Zukunft der Bodentruppen, *Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport (VBS),* 2019.: 48.
[1055] Human Machine Teaming (HMT), *UK Army*, https://www.army.mod.uk/our-future/human-machine-teaming/. (Accessed on 23.06.2023)
[1056] Buchard-Joubert, Aurélien. "Etude prospective sur l'emploi des robots terrestres à l'horizon 2050 : vers l'apparition d'un concept de dissuasion conventionnelle", Le Franc-Tireur Terre #02-2023, La Revue de l'Ecole de Guerre-Terre, *Ministère des Armées*.: 72-76.

- *Offensive tasks*: (a) harassing enemy units, (b) creating a diversion, (c) create a deception, (d) disorganising the enemy in depth, and (e) breaking through enemy defences.

For Point 2), the Swiss armed forces, supported by armasuisse and the SDRZ, should be inventive in developing and establishing new doctrinal concepts for military robotics. In particular, they could consider new ways of thinking about military concepts and doctrine, such as "Red Teaming" or the use of wargaming. Red Teaming is *"(…) a structured, iterative process that provides the command with an independent capability to continually challenge plans, operations, concepts, organizations and capabilities within the context of the operational environment."*[1057] It is acknowledged as a disruptive way of thinking that brings together people from outside the military organisation, from backgrounds as diverse as scientists, cartoonists, screenwriters and novelists. Its main objective is to *"(…) challenge the organization by providing alternatives through critical thinking in order to improve decision making and achieve the end state."*[1058] Several Western militaries have already established "Red Teams" and others are in the process of doing so.[1059] To move in this direction, armasuisse and the SDRZ may:

- Bring together people who think about the military outside the traditional framework in workshops and other more permanent structures.[1060] This can help at the strategic, operational and tactical levels.

- Create a group, or adapt an existing structure, within the armed forces' doctrine branch, tasked with carrying out forward-looking and "useful" studies on the future of armed conflict.[1061] The use of "useful fiction" provides fertile ground for conceptual reflection, particularly at the doctrinal level.[1062]

- Where appropriate, previous work by the US Army's project Decisive Action Training Environment (DATE) project, launched in 2020, should be replicated and adapted. DATE is designed as an evolving tactical training method, where operational environments may change and threats multiply.[1063]

[1057] *Ibid.: 84.* Translation by the authors.
[1058] Red Team handbook, *University of Foreign Military and Cultural Studies (UFMCS)*, 2012.: 3-4.
[1059] "Future Operating Environment (FOE) 2040", Planungsamt der Bundeswehr / Abteilung I – Zielbildung und Innovation (PlgABwI), *Bundeswehr*, 2023.
[1060] Red team. *Ces guerres qui nous attendent: 2030-2060*. Paris: Équateurs-PSL Université Paris, 2022.
[1061] The French land forces are, for example, currently setting up a "Red Team Terre" within the Centre de Doctrine et d'Enseignement du Commandement (CDEC).
[1062] Zenko, Micah. *Red Team: How to Succeed by Thinking like the Enemy*. New York: Basic Books, a member of the Perseus Books Group, 2015.
[1063] Decisive Action Training Environments, *US Army*, https://www.army.mil/standto/archive/2018/09/11/, 11 September 2018. (Accessed on 20.06.2023)

Recommendation 10*: Search and identify which standards, norms, and formats are to be implemented in the acquisition and use of military robotic systems for the Swiss armed forces.*

The Swiss Armed Forces, in cooperation with armasuisse and the SDRZ, can clarify which standards, norms and formats they wish to implement for the development and use of robotic systems. This is particularly relevant and necessary in the field of EDTs, which are rapidly evolving technologies whose development involves complex supply chains through several countries. Furthermore, as mentioned above, Switzerland needs to do this within the political and military framework of further engagement with NATO, the EU and other multilateral initiatives. All in all, the relevant actors at the respective levels (political, military, industrial) may:

1) Strengthen and deepen interoperability across the whole military spectrum with NATO and partner nations on military robotics norms and standards.

Interoperability can be defined as "(…) *the ability of military forces to train, exercise and operate effectively together coherently, effectively and efficiently to perform the missions and tasks assigned to them".*[1064] For Switzerland, a small country in the heart of Europe, interoperability is a key element enabling its armed forces to increase both their combat-readiness and their force development.[1065] In addition, interoperability – with its three components: technical (equipment, materials, test), procedural (doctrines, tactics, techniques and procedures (TTPs)) and human (language, training) – allows the Swiss armed forces to observe other ways of doing things in foreign armies, and to develop practices for implementing and using the technologies involved in a broader framework.[1066] In the field of standards, Switzerland has already defined 29 interoperability objectives and is working with several NATO instruments (NATO Industrial Advisory Group (NIAG), NATO Standardization Organization (NSO), NATO Support and Procurement Agency (NSPA), etc.) and is in the process of establishing a NATO Individually Tailored Partnership Programme (ITPP). The continuation of this work in the field of EDTs will be fundamental for Switzerland if it intends to increase its interoperability in the context of accelerated and disruptive technological developments. For this purpose, the Swiss armed forces, armasuisse and the SDRZ may:

- Enhance interoperability in military robotics with NATO at the technical and capability level, by replicating and, where appropriate, adapting already agreed or existing guidelines through the integration of these systems into the armed forces. Close study and monitoring of the development of STANAGs and other standards and norms will be particularly important in this area as well as a close cooperation with NIAG, NSO, and further developing ITPP.[1067]

- Develop interoperable procedures and doctrines for the use of military robotics in cooperation with NATO, by participating in workshops and discussions within the Joint Warfare Centre (JWC), the Doctrine Support Branch and the Joint Standardization

[1064] Glossaire interarmées de terminologie opérationnelle, *Centre Interarmées de Concepts, de Doctrine et d'Expérimentation (CICDE),* Paris, December 2013. Translation by the authors.
[1065] Currit, Laurent. "L'utilité de l'interopérabilité" in "Schweizer Partnerschaft mit der NATO – 20 Jahre Schweizer Teilnahme an der Partnerschaft für den Frieden", *Politorbis,* No.61, Zeitschrift zur Aussenpolitik, 2016.: 55.
[1066] Wanner, Peter. "Praktischen Nutzen des Partnerschaft für die Schweizer Armee" in "Schweizer Partnerschaft mit der NATO – 20 Jahre Schweizer Teilnahme an der Partnerschaft für den Frieden", *Politorbis,* No.61, Zeitschrift zur Aussenpolitik, 2016.: 52.
[1067] "Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung", CSS Briefing-Paper, *Center for Security Studies (CSS)*, ETH Zurich, August 2022.: 7-8.

Board (JSB).[1068] This would allow Switzerland not only to learn from other more advanced nations, but also to influence the process as a PfP member state.

- Implement interoperability in the process of training and education at all force levels regarding the integration and use of military robotics. The Swiss armed forces may seek to cooperate with NATO's Partnership Training and Education Centres (PTECs). PTECs aim, among other things, to develop Defence Capacity Building (DCB) and, Operational Capability Concepts (OCC) and have mobile expert training teams (METT) that can be used to train personnel from partner countries.[1069] Further cooperation with the GCSP – a NATO PTEC – would be useful to create lasting links in this area.

- Periodically test interoperability in its three components – capabilities, procedures and training – by participating in NATO exercises and other activities.[1070] To benefit from AAR, it is necessary to practice interoperability under realistic conditions. Participation in high-intensity exercises and training can be considered as a way of learning the challenges of separate planning and the limits of cooperation in practice.[1071]

- Promote interoperability through other multilateral initiatives, such as MCDC, which provides a good comprehensive tool for developing procedures and training as well as capabilities and forces. This also would allow Switzerland to work with and learn from a wider pool of countries, such as Japan, South Korea and Australia.[1072]

[1068] North Atlantic Treaty Organization, The JWC Doctrine Development Process*, NATO*, https://tinyurl.com/4e7rudcp, 9 May 2023. (Accessed on 22.06.2023)
[1069] NATO Partnership Training and Education Centres (PTECs) – "On the road to Training and Education", *NATO Defence Institution and Capacity Building Directorate*, Brussels, 2020.: 5-6.
[1070] As a reminder, Switzerland has already participated in NATO exercises, for example in the Arctic Challenge 2017 and Trident Juncture 2018.
[1071] "Sicherheits- und verteidigungspolitische Kooperation der Schweiz in Europa: Optionen zur Weiterentwicklung", CSS Briefing-Paper*, Center for Security Studies (CSS)*, ETH Zurich, August 2022.: 9.
[1072] Multinational Capability Development Campaign (MCDC) – Closing the Gaps in Multinational Operation, 2019.: 2.

Conclusion

An examination of the trends and implications of military robotics has shown that scientific, political and industrial factors are the main influences on technological development. Chapter 1 highlighted the long evolution of UAVs and the rapid development of unmanned ground and naval systems. It also showed that the spread of military robotic systems around the world depends largely on breakthroughs in related technologies such as sensors and AI. Chapter 2 showed that great power competition is a key driver of innovation in robotics, with major and middle powers competing to secure strategic technological advantages and/or dominate niche markets. Chapter 3 identified a growing ecosystem of pan-European supranational institutions and initiatives focused on defence innovation and technologies. It also showed that, despite renewed efforts by the EU and NATO to stimulate multinational technology development, most innovation R&D and production is still undertaken by states. Chapter 4 highlighted the relative uniqueness of the Swiss case, characterised by high levels of innovation, self-imposed political constraints related to its policy of neutrality, and a mismatch between civil and defence priorities. Chapter 5 made a series of ten recommendations in four policy areas to improve Switzerland's overall defence innovation efforts, and more specifically those related to military robotics.

In an international environment that some observers have called the "return of history", Switzerland faces security challenges. Regional and global trends are prompting Bern to consider further integration and deployment of military robotic systems. To improve the capability of Switzerland and the Swiss armed forces to develop, produce and use military robotic systems, four main areas should be targeted. First, in terms of security and defence policy, a pro-active attitude is needed on the part of Swiss innovation bodies in terms of cooperation with the EU, NATO and other multilateral cooperation. Second, with regard to the defence innovation ecosystem, the structure of certain institutions, such as the SDRZ, needs to be reviewed to ensure more effective development processes. Third, a new "ethos" of defence innovation should be promoted by better involving civilian actors in the development of technologies with military applications. Fourth, doctrines and standards should be adapted to ensure the smooth integration and responsible use of robotic systems across the full spectrum of military operations.

Military drones and robots are now a reality. Intensively used in guerrilla-style or inter-state conflicts such as Libya, Syria, Nagorno-Karabakh and Ukraine, these systems have paved the way for new ways of waging war. At the same time, these conflicts demonstrate that military robotic systems are not "wunderwaffen" that can turn the tide of battle on their own. Rather, they point to the need to use robotic systems to complement and enhance other conventional means: artillery fire support, infantry-level intelligence, or enhanced mechanised mobility. Wars are and will continue to be fought by humans. So, technology is only as good as the people who design, plan and use it. Similarly, a key lesson from the return of high-intensity warfare is that quantity is usually a quality. This has far-reaching implications for military planning and procurement policy, as the exponential technological advances of recent decades have led defence policymakers to favour quantity over quality in most western countries. In this regard, robotic systems can work both ways: they can reintroduce a dose of quantity into manpower-constrained militaries with cheap and scalable products, or they can reinforce the quality-driven paradigm by concentrating high-tech capabilities in a few highly advanced systems. As a result, defence policymakers will have the difficult task of preparing their forces to fight yesterday's wars while ensuring that they develop the capabilities to win tomorrow's. Military robotic systems do not offer a simple, all-encompassing solution to this challenge.

Appendix

Table 1. Typology of the spectrum of autonomy in robotic systems.[1073]

Level of automation	***Command-and-control relationship***	***Definition***
Semi-autonomous	Human-in-the-loop	Systems that require some form of human interaction to perform a specific policy task
Human-supervised autonomous	Human-on-the-loop	Systems can act and execute policy tasks independently, yet humans still have oversight over their executions of these policy tasks.
Fully autonomous	Human-out-of-the-loop	Systems that can act in total independence from human supervision

Table 2. Typology of military robotic systems with sub-categories.[1074]

Categories	***Sub-categories***	***Examples***
UAVs	Combat UAVs (UCAVs)	MQ-4C (USA)
UAVs	ISR drones	Eitan (Israel)
UAVs	Hypersonic drones	GJ-11 (China)
UAVs	Loitering munition	Harpy (Israel)
UGVs	Weaponised uncrewed land systems	Uran-9 (Russia)
UGVs	Squad multi-purpose equipment transport	Cheehat (USA)
UUVs & USVs	Autonomous underwater vehicles (AUVs)	D3000 (China)
Swarms	ISR swarms	Perdix (USA)
Swarms	Anti-access/area-denial (A2/AD)	Golden Eagle 150B (China)
Swarms	Distributed attacks	Kargu (Turkey)

[1073] Table made by authors. *Source:* Verbruggen, Maaike and Boulanin, Vincent. "Mapping the Development of Autonomy in Weapon Systems", *Stockholm International Peace Research Institute (SIPRI)*, 2017.: 5-6. Further reading on the interaction between humans and robots in: Horowitz, Michael and Scharre, Paul. "Meaningful Human Control in Weapon Systems: A Primer", *Center for New American Security*, 2015 and others. The classification of armed military robotic systems into the three primary categories presented has also been mentioned by Singer, Paul. "Outsourcing War to Machines: The Military Robotics Revolution", *ABC CLIO*, 2018.: 8 and others.

[1074] Table made by authors. *Sources*: Michael Chase et al., Emerging Trends in China's Development of Unmanned Systems, *RAND Corporation*, 2015.; Bode, Ingvild and Huelss, Hendrik. "Autonomous weapons systems and changing norms in international relations", *Review of International Studies*, Vol. 44 Issue 4, 2018.: 402.; Bradley Martin et al., "Advancing Autonomous Systems. An Analysis of Current and Future Technology for Unmanned Maritime Vehicles", *RAND Corporation*, 2019.; Leftwich, James et al., Supporting Combat Power Projection Away from Fixed Infrastructure, *RAND Corporation*, 2022.

Table 3. US military robotic systems in service of the armed forces.[1075]

Type of robotics (Class of UAV)[1076]	Name	Operated by	Manufacturer	Year of acquisition/latest news	Development Status[1077]
			UAVs		
UAV I	MQ-1C Gray Eagle	Army	GA-ASI	2009	Fielded
UAV I	Aurora Goldeneye	Army, Marines	Aurora Flight Sciences	2003	Fielded
UAV I	Skylynx II	Army, Marines	BAE Systems	2006	Fielded
UAV I	AQM-37 Jayhawk	Air Force	Beechcraft	-	Fielded/Retired
UAV I	Albatross	Army, Marines, Navy	Applied Aeronautics	2018	Fielded
UAV I	Silver Fox	Army, Marines, Navy	BAE Systems	2015	Fielded
UAV I	T-20	Army, marines	AeroVironment	2021	Development
UAV I	FQM-151 Pointer	Army, Marines	Aero Vironment	Mid-1980s	Fielded/Retired
UAV I	RQ-14 Dragon Eye	Army, Marines	Aero Vironment	2002	Fielded
UAV I	Nano Hummingbird	Army, Marines	Aero Vironment	2011	Fielded
UAV	RQ-6 Outrider	Army, Marines, Navy	Alliant Techsystems	1999	Fielded
UAV I	SkyRanger (Canada)	Marines, Air Force	Aeryon Labs	Mid-2010s	Fielded
UAV I	Switchblade (300/600)	Army, Marines	Aero Vironment	Mid-2010s	Fielded
UAV I	RQ-11B Raven	Army, Marines	Aero Vironment	2006	Fielded
UAV I	RQ-20 Puma	Army, Air Force, Marines	Aero Vironment	2008	Fielded
UAV I	RQ-12 Wasp	Marines, Special Forces	Aero Vironment	-	Fielded
UAV	ScanEagle	-	Insitu	2004	Fielded

[1075] Table made by authors. *Sources*: Hoehn, John R. and Kerr, Paul. "Unmanned Aircraft Systems: Current and Potential Programs", *Congressional Research Service*, Report, No. 47067, 2022.; O'Rourke, Ronald. "Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress", *Congressional Research Service*, No. 45757, 2022.; Feickert, Andrew. "Marine Corps Advanced Reconnaissance Vehicle" (ARV), *Congressional Research Service*, *In Focus*, 23 March, 2023.; U.S. Ground Forces Robotics and Autonomous Systems (RAS) and Artificial Intelligence (AI): Considerations for Congress, *Congressional Research Service*, 2018.; Feickert, Andrew. "The Army's Optionally Manned Fighting Vehicle (OMFV) Program: Background and Issues for Congress", *Congressional Research Service*, No. 45519, 2021.; Gettinger, Dan. "The Drone Databook", *The Center for the Study for the Study of the Drone at Bard College*, 2019.; List of unmanned aerial vehicles, *Wikipedia,* (Accessed on 08.12.2022) and others.

[1076] Classes I, II & III refer to the weight of each system, which is indicative of the type of operation it can complete. Class I = less than 150 kg; Class II = 150 to 600 kg; and Class III more than 600 kg (according to the classification of NATO STANAG 4670). Accountable for Table 3-7.

[1077] Levels of development status identified by the authors (for Table 3-9) are: a) Research, b) Development, c) Production, d) Fielded, e) Fielded/Retired, f) In storage.

UAV I	RQ-21 Integrator	Marines	Insitu	-	Development
UAV I	Instant Eye Mk2 Gen 3	Marines	Physical Sciences	Mid-2010s	Fielded
UAV I	Stalker	Special Forces	Lockheed Martin	-	Fielded
UAV I	MQ-19 Aerosonde	Special Forces	AAI	2019	Development
UAV I	RQ-15 Neptune	Navy	DRS	2002	Fielded
UAV I	Sentry HP	Navy	DRS	2002	Fielded
UAV I	RQ-16 T-Hawk	Army, Marines	Honeywell	2010	Fielded
UAV I	XFC (submarine-launched)	Navy	US Naval Research Laboratory	2013	Development
UAV	Blackwing (submarine-launched)	Navy	Aero Vironment	2023	Fielded
UAV I	Bat (Killer Bee)	Army	Northrop Grumman	2006	Fielded
UAV II	SIERRA	Navy, NASA	US Naval Research Laboratory	2009	Development
UAV II	Tern	Navy	Northrop Grumman	-	Research
UAV II	Global Observer	Army, Marines, Navy	Aero Vironment	2010	Development
UAV II	RQ-7 Shadow	Army	Textron	2003	Fielded
UAV II	MQM-107 Streaker	Air Force, Navy	Beechcraft	1984	Fielded
UAV II	RQ-23 Tigershark	-	Navmar Applied Sciences Corp.	2022	Development
UAV III	MQ-9 Reaper	Air Force	GA-ASI	2007	Fielded
UAV III	Firebird Model 355	Air Force, Navy	Northrop Grumman	2010	Fielded
UAV III	MQ-20 Avenger	Air Force	GA-ASI	2009	Fielded
UAV III	X-45A/B/C/N	Air Force	Boeing	2000-2009	Fielded
UAV III	Phantom Ray	Air Force	Boeing	-	Development
UAV III	X-47 A/B/C Pegasus	Navy	Northrop Grumman	2003	Fielded
UAV III	X-56A	Air Force, Navy, NASA	Lockheed Martin	2013	Fielded
UAV III	A160 Hummingbird	Air Force, Navy	Boeing	2002	Fielded/Retired
UAV III	Eagle Eye	Air Force, Navy	Bell Helicopter	1998	Fielded
UAV III	X-51 Waverider (hypersonic)	Air Force	Boeing	2022	Production
UAV III	MQ-25 Stingray	Navy	Boeing	Expected 2025	Fielded

UAV III	Altus	Air Force, NASA	General Atomics	1997	Fielded
UAV III	Orion	Air Force, Navy	Aurora Flight Sciences	2010	In storage
UAV III	RQ-4 Global Hawk	Air Force	Northrop Grumman	2001	Fielded
UAV III	MQ-4C Triton	Air Force	Northrop Grumman	2018	Fielded
UAV III	RQ-170 Sentinel	Air Force	Lockheed Martin	2007	Fielded
UAV III	B-21 Raider	Air Force	Northrop Grumman	2022	Development
UAV III	MQ-1 Gray Eagle	Air Force	GA-ASI	2004	Fielded
UAV III	RQ-1 Predator	Air Force, Army	GA-ASI	1995	Fielded/Retired
UAV III	RQ-180	Air Forces	Northrop Grumman	2019	Development
UAV III	RQ-5 Hunter	-	Northrop Grumman, IAI	1995	Fielded
UAV III	MQ-8B Fire Scout	Navy	Northrop Grumman	2007	Fielded
UAV III	MQ-8C Fire Scout	Navy	Northrop Grumman	2019	Fielded
UAV III	PD-100 Black Hornet 2	Army, Marines	FLIR Systems	2016	Fielded
UAV III	XQ-58 Valkyrie	Air Force	Kratos Defense & Security Solutions	2019	Development
UAV III	X-61A Germlins	-	Dynetics Gremlins	2020	Development
UAV III	AD 150	Marines, Navy	American Dynamics	2008	Fielded
UAV III	ALIAS Black Hawk	Army, Navy, Marines	Lockheed Martin, Sikorsky, DARPA	2022	Development
Swarm	Piccolissimo	Army, Marines	University of Pennsylvania	2017	Development
			UGVs		
UGV	Squad Multi-Purpose Equipment Transport (SMET)	Army, Marines, Special Forces	Robotic Research	2021	Development
UGV	RCV-L	Army	QinetiQ Inc.	2023	Development
UGV	Ripsaw M5 RCV-M	Army	Textron & How&Howe's	2023	Development
UGV	RCV-H	Army	-	2023	Development
UGV	Leader-Follower Technology for Tactical Wheeled Vehicles (LF/TWV)	Army, Marines	Ground Vehicle Systems Center	2021	Development

UGV	Marine Corps Expeditionary Modular Autonomous Vehicle (EMAV)	Marines	Pratt & Miller	2021	Research
UGV	Marine Corps Advanced Reconnaissance Vehicle (ARV)	Marines	Textron Cottonmouth & General Dynamics	2023	Development
UGV	Optionally Manned Fighting Vehicle (OMFV)	Army, Marines	Oshkosh Defense, Point Blank Enterprises, BAE Systems, Rheinmetall Vehicles, General Dynamics Land Vehicles (Contract not awarded yet)	2021	Research
UUV/USVs					
USV	Overlord USV1 Nomad	Navy	Vigor Industrial & L3 Harris Technologies	2021	Development
USV	Overlord USV2 Ranger	Navy	-	2022	Development
USV	Overlord USV3 Vanguard	Navy	Kongsberg	2022	Development
USV	Overlord USV4 Mariner X	Navy	Maritime Robotics	2022	Development
USV	MUSV #1	Navy	L3 Harris Technologies	2022	Development
USV	Sea Hunter	Navy	Vigor Industrial	2022	Development
USV	Seahawk	Navy	Vigor Industrial	2021	Fielded
UUV	Orca XLUUV	Navy	Boeing	2021	Fielded
UUV	NMRS	Navy	-	2020	Captured by North Korea
UUV	Pharos	Navy	Huntington Ingalls Industries	2022	Development
UUV	Proteus	Navy	Huntington Ingalls Industries	2022	Fielded
UUV	Echo Voyager	Navy	Boeing	2019	Fielded
UUV tracked	Bayonet 150/250/350	Special Forces	Bayonet Ocean Vehicles	2023	Development
UUV	SwarmDiver	Marines, Special Forces	Aqua Botix	2019	Fielded
UUV	Snakehead LUUV	Navy	Naval Undersea Warfare Center	2022	Development

Table 4. Chinese military robotic systems in service of the armed forces.[1078]

Type of robotics (Class of UAV)	Name	Operated by	Manufacturer	Year of acquisition/latest news	Development Status
			UAVs		
UAV I	Chang Hong 1	Army, Special Forces, Navy	China Academy of Aerospace Aerodynamics & ALIT	Mid-2000s	Fielded
UAV I	Chang Hong 2	Army, Special Forces, Navy	China Academy of Aerospace Aerodynamics & ALIT	Mid-2000s	Fielded
UAV I	Chang Hong 802	Army, Navy, Air Force	China Academy of Aerospace Aerodynamics & ALIT	-	Fielded
UAV I	Chang Hong 817	Army, Special Forces	China Academy of Aerospace Aerodynamics & ALIT	2021	Production
UAV I	Chang Hong 901	Army, Special Forces	China Academy of Aerospace Aerodynamics & ALIT	2012	Fielded
UAV I	Chang Hong 902	Army, Special Forces	China Academy of Aerospace Aerodynamics & ALIT	2016	Fielded
UAV I	Blowfish 1	Air Force	Ziyan	2018	Fielded
UAV I	Harpy (ASN-301)	Army, Special Forces	IAI (Israel)	1999	Fielded
UAV I	KWT-6L	Army, Special Forces	All Tech	2014	Fielded
UAV I	YZ-6	Army, Air Force	BMP	-	Fielded
UAV I	CK-GY01	Army, Special Forces	CASM	-	Fielded
UAV I	CK-GY02	Army	CASM	-	Fielded
UAV I	CK-GY03	Army	CASM	-	Fielded
UAV I	CK-GY04	Army, Navy	CASM	2011	Fielded

[1078] Table made by authors. *Sources*: Gettinger, Dan. “The Drone Databook”, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; Alden, Chris et al., “Wings Along the BRI. Exporting Chinese UCAVs and Security?”, *LSE Ideas Strategic Update*, 2020: 9; China Power, Is China at the Forefront of Drone Technology?, *Center for Strategic and International Studies (CSIS)*, 2018.; Mastro, Oriana Skylar. “Beijing's line on the South China Sea: Nothing to see here”, *The Interpreter by the Lowy Institute*, 2020.; Annual Report to Congress: Military and Security Developments Involving the People's Republic of China, *Office of the Secretary of Defense*, 2021: 57.; Chase, Michael et al. “Emerging Trends in China's Development of Unmanned Systems”, *RAND Corporation*, 2015; Paszak, Pawel. “Are Military Drones the Future of the Chinese Army?”, *Warsaw Institute*, 2020.; List of unmanned aerial vehicles of China, *Wikipedia,* (Accessed on 08.12.2022) and others.

UAV I	CK-HW13	Army, Navy	CASM	2011	Fielded
UAV I	CADI-1	Army	Chengdu Aircraft Design Institute (CADI)	2011	Fielded
UAV I	VD200	Army	CADI	-	Fielded
UAV I	VMA-01	Army, Navy	CADI	-	Fielded
UAV I	CADI Leap Dragon	Army, Navy	CADI	2015	Fielded
UAV I	CY-105	Army	Chaoyi	2014	Fielded
UAV I	CY-208	Army, Navy	Chaoyi	2014	Fielded
UAV I	CY-01 Hua Ying	Army	Chunyi	2013	Fielded
UAV I	CY-05 Falcon	Army, Special Forces	Chunyi	2013	Fielded
UAV I	CY-06 Shooting Star	Army	Chunyi	-	Fielded
UAV I	CY-07	Army	Chunyi	2013	Fielded
UAV I	CY-08 Flying Saucer	Army	Chunyi	2013	Fielded
UAV I	CY-10	Army	Chunyi	2015	Fielded
UAV I	CY-X6	Army, Special Forces	Chunyi	2015	Fielded
UAV I	Phantom 1/2/3/4	Army, Special Forces, Navy	DJI	2015-2018	Fielded
UAV I	Mavic 1/2	Army, Special Forces, Navy	DJI	2019-2021	Fielded
UAV I	Spreading Wings S800/EVO	Army, Special Forces	DJI	2013	Fielded
UAV I	Agras	Army, Special Forces	DJI	-	Fielded
UAV I	Ghost	Army, Special Forces	Guangzhou EHang Intelligent Technology (EHang)	-	Fielded
UAV I	EHang 184	Army, Special Forces	Ehang	-	Fielded
UAV I	Quadcopter	Army	Jiangsu ShenGu Unmanned Aerial Vehicle Technology (JSSG)	2015	Fielded
UAV I	Hexacopter	Army	JSSG	2015	Fielded
UAV I	HY-B-10L	Army, Special Forces	Shenzen High-Tech New Agricultural Co. (HTNA)	2014	Fielded
UAV I	Flying Lion	Army, Navy	Nanjing University od	2011	Fielded

			Science and Technology (NUST)		
UAV I	Aerial Droid	Army, Special Forces	Northwestern Polytechnical University (NWPU)	2014	Fielded
UAV I	BJ6903/MFW	Army, Special Forces	NPWU	-	Fielded
UAV I	Spider-Man ZZX	Army	SYADI	-	Fielded
UAV I	Stroller	Army, Air Force, Navy	PLAAF	2011	Fielded
UAV I	PowerCopter	Army, Air Force	PowerVision Technology	2015	Fielded
UAV I	PowerQuad	Army, Special Forces	PowerVision Technology	2015	Fielded
UAV I	PowerOcta	Army, Special Forces	PowerVision Technology	2015	Fielded
UAV I	PowerSeeker	Army, Special Forces	PowerVision Technology	2015	Fielded
UAV I	Octocopter	Army	Taihua	2014	Fielded
UAV I	3M-Ranger	Army, Special Forces	Sparkie Tech	2014	Fielded
UAV I	Ranger-X	Army, Special Forces	Sparkie Tech	2014	Fielded
UAV I	TH-703/805	Army, Special Forces	Tianjin Tian-Hen-Zhi-Yuan Science and Technology (THZY)	2014	Fielded
UAV I	TH-1040/1240	Army	THZY	2014	Fielded
UAV I	Contingency Responder II/V	Army	Guilin Xinying Electronic Science & Technology (Xinying)	2011-2013	Fielded
UAV I	TY-X8	Army, Special Forces	Xi'an Sky Wing Aviation Science and Technology (TiANY)	2014	Fielded
UAV I	Wayulink Quadcopter	Army	Shenzen Wayulink Technology (Wayulink)	2014	Fielded
UAV I	3WDN40-6/10/15/18	Army	ZHYR	2015	Fielded
UAV II	ASN-209	Navy	Xi'an ASN Technology Group	2011	Fielded
UAV II	ASN-207	Army	Xi'an ASN Technology Group	Early 2000s	Fielded
UAV II	ASN-206	Army	Xi'an ASN Technology Group	Mid-1990s	Fielded

UAV II	Yz-8	Army, Air Force	BMP	-	Fielded
UAV II	XLB Patroller	Army, Navy	SYADO	2015	Fielded
UAV II	Camcopter S-100	Navy	Schiebel	2010	Fielded
UAV II	Hiwing-600 (Sky Hawk)	Army, Navy, Air Force	China Aerospace Science and Industry Corporation (CASIC)	Early 2010s	Fielded
UAV II	Hiwing-610	Army, Air Force, Navy	CASIC	Mid-2010s	Fielded
UAV II	RU100/200	Army, Air Force, Navy	Elecpro	2014	Fielded
UAV II	Chang Hong 3	Army, Air Force	China Academy of Aerospace Aerodynamics & ALIT	Mid-2000s	Fielded
UAV III	RU650	Air Force, Navy	Elecpro	-	Fielded
UAV III	Chang Hong 4	Air Force	China Academy of Aerospace Aerodynamics & ALIT	2010	Fielded
UAV III	Chang Hong 5	Air Force	China Academy of Aerospace Aerodynamics	2017	Fielded
UAV III	Chang Hong 6	Air Force	China Academy of Aerospace Aerodynamics & ALIT	2021	Development
UAV III	Chang Hong 7	Air Force	China Academy of Aerospace Aerodynamics & ALIT	2022	Production
UAV III	Chang Hong 803	Air Force, Navy	China Academy of Aerospace Aerodynamics & ALIT	2011	Fielded
UAV III	Chang Hong 10	Air Force, Navy	China Academy of Aerospace Aerodynamics & ALIT	2022	Development
UAV III	Chang Hong 91 (BZK-008)	Air Force, Navy	China Academy of Aerospace Aerodynamics & ALIT	2022	Development
UAV III	Chang Hong 92	Air Force, Navy	China Academy of Aerospace Aerodynamics & ALIT	2020	Fielded
UAV III	Wing-Loong 1 (Chengdu GJ1)	Air Force	Chengdu Aircraft Industry Group	2009	Fielded
UAV III	Wing-Loong 2 (Chengdu GJ2)	Air Force	Chengdu Aircraft Industry Group	2018	Fielded

UAV III	Wing-Loong 3 (Chengdu GJ3)	Air Force	Chengdu Aircraft Industry Group	2022	Production
UAV III	Wing-Long 10 (WZ 10)	Air Force	Chengdu Aircraft Industry Group	2016	Fielded
UAV III	BZK-005	Navy	Beihang	2007	Fielded
UAV III	BZK-007	Army	Beihang	-	-
UAV III	WZ-7 Soar Dragon	Air Force	Guizhou Aircraft Industry Corporation (GAIC)	2018	Fielded
UAV III	WZ-8	Air Force	Aviation Industry Corporation of China	2020	Fielded
UAV III	Tengden TB001	Air Force	Sichuan Tengden Technology Company	2021	Production
UAV III	Tianying Skyhawk	Air Force	China Aerospace Science and technology Corporation	2022	Production
UAV III	Yaoying-III	Air Force	GAIC	2019	Production
UAV III	Chank Kong-2	Air Force	Nanjing	Mid-1990s	Fielded
UAV III	CR500 Golden Eagle	Air Force, Navy	North Industries Group Corporation Limited (NORINCO)	2020	Production
UAV III	CK-1A/B/C/E	Air Force	Nanjing Aviation Institute (NAI)	Mid-1970s	Fielded/Retired
UAV III	BA-5	Air Force	Shenyang Aircraft Manufacturing Factory (SAMF)	Mid-1970s	Fielded/Retired
UAV III	Divine Eagle	Air Force	SADI	2018	Fielded
UAV III	Hongdu GJ-11 Sharp Sword	Air Force	Shenyanf Aircraft Design Institute (SYADI)	2019	Fielded
UGVs					
UGV	Sharp Claw 1	Army	NORINCO	2021	Production
UGV	Sharp Claw 2	Army	NORINCO	2021	Development
UGV	Mule-200	Army	Zhong Tian Zhi Kong Technology	2020	Production

			Holdings Company		
UUV/USVs					
UUV	Sea-Whale 2000	Navy	CAS' Shenyang Institute of Automation	2019	Development
UUV	Qianlong-1	Navy	CAS' Shenyang Institute of Automation	2013	Fielded
UUV	Haiyi 7000	Navy	CAS' Shenyang Institute of Automation	2012	Fielded
UUV	Weilong 1/2/3	Navy	China Shipbuilding Industry Corporation	-	Development
UUV	Haishen 100 (Poseidon)	Navy	China Shipbuilding Industry Corporation (CSIC)	Mid-2010s	Development
UUV	Explorer (Tan Suo Zhe)	Navy	CSIC	2014	Development
UUV	HSU001	Navy	-	-	Development
UUV	SPICE	Navy	-	-	Research
UUV	Haidou 1	Navy	CAS' Shenyang Institute of Automation	2020	Development
USV	Tianxing-1	Navy	Harbin Engineering University	2018	Production
USV	Marine Lizard (amphibious IFV)	Navy, Army	CSIC	2019	Development
USV	JARI	Navy	CSIC	2018	Production

Table 5. Russian military robotic systems in service of the armed forces.[1079]

Type of robotics (Class of UAVs)	Name	Purpose[1080]	Manufacturer	Latest news (year)	Development Status	Deployed in Ukraine?
			UAV/UCAVs			
UAV I	Volk-18	ISR, combat	Almaz-Antey	2021	Development	No
UAV I	Eleron-3SV	ISR	ENICS	2016	Fielded	Yes
UAV I	Eleron-7	ISR	ENICS	2019	Fielded	No
UAV I	Granat 1/2/4	ISR	Kalashnikov	2015	Production	Yes
UAV I	Lastochka-M	ISR	"Luch" Design Bureau	2018	Fielded	Yes
UAV I	Zastava	ISR	UZGA	2016	Production	Yes
UAV I	Orlan-10	EW, ISR	Special Technology LLC	2021	Production	Yes
UAV I	Orlan-30	EW, ISR	Special Technology LLC	2021	Production	Yes
UAV I	Dobrynya	ISR, combat	Almaz-Antey	2023	Production	No
UAV I	PTERO-GO	ISR	AFM Servers	2016	Fielded	No
UAV I	Feniks	ISR	TAIP	2019	Development	No
UAV I	Fregat	ISR	Kronstadt	2020	Development	No
UAV I	GSV-37 BREEZE	Recon, patrol	Radar MMS	?	Development	No
UAV I	Karnivora	ISR, combat	NPP Mikran	2018	Development	No
UAV I	Argument	-	-	-	Research	No
UAV I	Takhion	ISR	Izhmash	2017	Fielded	Yes
UAV I	Lantset-1/ 3 (loitering munition)	Recon, combat	Rostec	2019	Fielded	Yes
UAV I	Strekoza	Recon, combat	-	-	Development	No
UAV I	Veer	ENICS	ISR, combat	2019	Development	No

[1079] Table made by authors. *Source*: Edmonds, Jeffrey et al., "Artificial Intelligence and Autonomy in Russia", *Center for Naval Analyses (CNA)*, 2021: Appendix D.; Allik, Sten et al. "The Rise of Russia's Military Robots – Theory, Practices and Implications", *International Centre for Defence and Security*, 2021.: A1-C2.; Bendett, Samuel et al. "Advanced military technology in Russia – Capabilities and implications", *Chatham House*, Research Paper, 2021.: 47-62.; Edmonds, Jeffrey and Bendett, Samuel. "Russia's Use of Uncrewed Systems in Ukraine", *The Center for Naval Analyses (CNA)*, May 2023.: 40-41.; and others.
[1080] In contrast to the United States and China, sources on Russian military robotics refer most of the time to "purpose" rather than to units of the armed forces that operate the systems. This column gives an idea of the potential use of each system within the Russian armed forces.

UAV I	Voron-777	EW, ISR	Iskat Design Bureau	2019	Development	No
UAV I	Fixar-007	ISR	FIxar Global	2020	Production	No
UAV I	Nanorazvedchik	ISR	Decima	2021	Development	No
UAV I	TAKR-7001	ISR	LLC Aviation	2018	Fielded	No
UAV I	LA-251 Sova	ISR	Tiber Company	2020	Fielded	No
UAV II	Horizon Air S-100 (Camcopter S-100)	Recon	Scheibel	-	Fielded	No
UAV II	Katran	Recon, stealth attack	Russian Helicopter Group	2019	Development	No
UAV II	Korsar	EW, ISR	“Luch” Design Bureau	2018	Development	Yes
UAV II	Zala VTOL	ISR	Rostec	2021	Production	Yes
UAV II	Kartograf	ISR	Special Technology Center	2022	Fielded	Yes
UAV II	Eleron-10SV	ISR	ENICS	2020	Development	No
UAV II	Kub-BLA (loitering munition)	Combat	Kalashnikov	2019	Fielded	Yes
UAV II	VRT300	ISR	Russian Helicopters	2017	Fielded	No
UAV II	Albatros-2	ISR	UAVOS	2021	Fielded	No
UAV II	Aura-100	ISR, combat	AURA	2022	Development	No
UAV II	Shahed-136/131 (loitering munition)	Combat	Shahed Aviation Industries (Iran)	2022	Fielded	Yes
UAV II	Shahed 129/191	ISR, combat	Shahed Aviation Industries (Iran)	2022	Fielded	Yes
UAV III	Gubkin	ISR, combat	Gubkins University	-	Development	No
UAV III	CHIROK	EW, ISR	Moscow Radio Engineering Research Institute	2014	Fielded	No
UAV III	Okhotnik S-70	Combat, ISR, stealth attack	Novosibirsk Aircraft Production Association Plan (NAPAP)	Expected 2024	Production	No
UAV III	Altius	ISR, combat?	UZGA	2019	Fielded	No
UAV III	DOZOR-600	ISR	Kronstadt Group	2015	Fielded	No
UAV III	E080 Berta	ISR, targeting	ENICS	2019	Development	No

UAV III	Orion	ISR, combat	Kronstadt	2018	Production	No
UAV III	Forpost	ISR	UZGA	2020	Production	No
UAV III	Mikoyan SKAT	Combat	Russian Aircraft Corporation MiG	?	Development	No
UAV III	Okhotnik-B	ISR, combat	Sukhoi	2019	Development	No
UAV III	Grom	Combat	Kronshtadt	2020	Development	No
UAV III	Sirius/Helios	Combat	Kronshtadt	2020	Research	No
UAV III	Mohajer-6	ISTAR, combat	Qods Aviation Industry Company (Iran)	2022	Fielded	Yes
UAV	R-2200	-	-	-	Fielded	No
UAV	Briz	ISR	Radar MMS	2020	Development	No
UAV	Grach	-	-	-	Development	No
UAV	BANS	-	-	-	Development	No
UAV	Glaz	-	-	-	Fielded	No
UAV	Gonshichik	-	RSK MiG	2020	Development	No
Swarm	Molniya	Swarming, combat	Kronshtadt	2020	Development	No
Swarm	Staya-93	Swarming, combat	Gagarin Air Academy	-	Development	No
UGVs						
UGV	Krymsk	Logistics	Military-Industrial Complex	2016	Development	No
UGV	Udar	Combat	Rostec	2021	Fielded	No
UGV	Marker	Recon	Android Tekhniva & ARF	2019	Fielded	No
UGV	Uran-6/9/14	Demining, combat	Rostec	2020	Production	Yes
UGV	Soratnik	Combat	Rostec	2015	Fielded	No
UGV	Nahlebnik	Combat	Kalashnikov	2018	Fielded	No
UGV	Strelok	Recon, patrol	Special Construction Machinery Ltd.	2013	Fielded	No
UGV	Companion	Recon, patrol	Kalashnikov	2020	Development	No
UGV	Nerekhta	Logistics, combat	Degtyaryov Plant & ARF	2017	Development	No
UGV	Shturm	Combat	Uralvagonozavod	2020	Development	No
UGV swarm	Kungas	Recon, combat	SKBM	2020	Fielded	No

UGV	Paladin	Combat, logistics	Signal Research Institute	2019	Development	No
UGV	Argo R8 (US)	Logistics	Argo	-	Fielded	No
UGV	Mars A-800	Logistics	Design Bureau Aurora	2019	Fielded	No
UGV	Freeloader	Combat, EOD	Kalashnikov	2020		No
UGV	Passage	Demining	Signal Research Institute	2015	Fielded	No
UGV	Scarab	Demining	CET-1	2022	Fielded	Yes
UGV	Sphera	Demining	CET-1	-	Production	No
UGV	Scorpio	Combat	-	-	Fielded	No
UGV	Platforma-M	Multi-purpose, combat	NITI Progress	2015	Fielded	No
UGV	Prohod-1	Demining	High Precision Weapons JSC	2021	Fielded	Yes
UGV	Kapitan	Engineering, demining	Izhevsk Radio Plant	2019	Development	No
UGV	MRK-15	-	Izhevsk Radio Plant	-	Production	No
UGV	MRK-002/27	Recon, patrol	Izhevsk Radio Plant	2016	Production	No
UGV	KRMM-06	Multi-purpose	Polus-ST	2019	Production	No
UGV	Kobra-1600	Demining	-	-	Production	No
UGV	Evakutsia	-	-	-	Research	No
UGV	T-14 Armata (MBT)	Combat	Rostec	2022	Fielded	No
Humanoid UGV	Fedor	Combat, space exploration	Android Technics Research	2019	Fielded	No
Humanoid UGV	Teledroid	Space exploration	Android Technics Research	Expected 2024	Development	No
UUVs/USVs						
USV	Kadet-M	-	Center for the Development of Innovation Activity (SPbPU)	2022	Fielded	No
USV	CyberBoat-350	-	-	-	Development	No
USV	Iskatel	Combat, ISR	Rubin Central Bureau of Maritime design	2017	Development	No
USV	Skanda	Combat, ISR	Mnev and Co. Shipbulding	2018	Development	No
USV	Buk-600	Combat, ISR	St.Petersburg State Marine	2018	Development	No

			Technical University			
UUV	Poseydon	Nuclear deterrence	Rubin Central Design Bureau	2019	Fielded	No
UUV	Galtel	ISR demining	Institute of Marine Technology Problems	2012	Fielded	No
UUV	Inspektor MK-2	Combat, ISR	ECA Group (FR)	2019	Development	No
UUV	Vityaz	ISR	Rubin Central Design Bureau & ARF	2017	Fielded	No
UUV	Klavesin-1/2R	ISR	Rubin Central Design Bureau	2018	Development	No
UUV	Yunona	Research	Rubin Central Design Bureau	2018	Development	No
UUV	Amulet	Research	Rubin Central Design Bureau	2018	Development	No
UUV	Kontsept-M	Recon	Tetis Pro	2014	Production	No
UUV	Garmoniya-GID	-	Rubin Central Design Bureau	2018	Development	No
UUV	Gavia	Research, recon	Teledyne Gavia	2013	Fielded	No
UUV	Glayder-T; 2.0	Ew, recon	“Compass” Moscow Design Bureau	2016	Development	No
UUV	Marlin-350	Research, rescue, guarding, engineering	Tetis Pro	2016	Production	No
UUV	Sea Shadow	-	St.Petersburg State Marine Technical University	2017	Production	No
UUV	Sarma	Arctic ISR	Strikepod Systems	2021	Development	No
UUV	Avora	ISR	SSM	2015	Development	No
UUV	Surrogat	Recon, research	Rubin Central Design Bureau	2020	Development	No
UUV	Cephalpod	Combat	Rubin Central Design Bureau	2015	Development	No
UUV	Nerpa	Patrol	Rostec	2018	Development	No
UUV	Iceberg	-	-	-	Development	No
UUV	Perspectiva-R	-	-	-	Research	No
UUV	MSS-3000	Research	Marine Geo Service	-	Production	No
UUV	Skat	ISR, MCM	Spektr Engineering	2023	Fielded	No
UUV	LI UUV	Demining	Okeanos	2022	Fielded	No

Table 6. Israelian, Australian and Turkish military robotic systems in service of the armed forces.[1081]

Country	Type of robotics	Name	Origin	Manufacturer	Year (news/field)	Development status
Israel	***UAV***	Heron MK II	Israel	IAI	2020	Development
	UAV	Casper 250	Israel	Top I Vision	-	Development
	UAV	Silver Arrow Mini-V	Israel	Elbit Systems	1990	Fielded
	UAV	Silver Arrow Sniper	Israel	Elbit Systems	1990	Fielded
	UAV	I-View	Israel	IAI	2006	Fielded
	UAV	Panther	Israel	IAI	2012	Fielded
	UAV	Ranger	Israel/CH	IAI/RUAG	1999	Fielded/Retired
	UAV	Eitan	Israel	IAI	2009	Fielded
	UAV	RQ-2 Pioneer	US	AAI	1986	Fielded/Retired
	UAV	RQ-7 Shadow	US	AAI	2002	Fielded
	UAV	Bird-Eye	Israel	IAI	2004	Fielded
	UAV	Dominator	Israel	Aeronautics Defense Systems	2009	Fielded
	UAV	Orbiter	Israel	Aeronautics Defense Systems	2015	Fielded
	UAV	Cormorant	Israel	Tactical Robotics	2020	Development
	UAV	Mastiff	Israel	Tadiranc Electronic Systems	-	Fielded/Retired
	UAV	Harop (loitering munition)	Israel	IAI	2013	Fielded
	UAV	Harpy (loitering munition)	Israel	IAI	-	-
	UAV	Phantom	China	DJI	2017	Fielded
	UAV	Mavic	China	DJI	2017	Fielded
	UAV	Matrice	China	DJI	2017	Fielded

[1081] Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Gettinger, Dan. “The Drone Databook”, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; List of unmanned aerial vehicles, *Wikipedia,* (Accessed on 08.12.2022); Turkey – Armed Drones in the Middle East, *Royal United Services Institute (RUSI)*, (Accessed on 12.10.2023) and others.

	UAV	Skylark	Israel	Elbit	2004	Fielded
	UAV	Skylark 3	Israel	Elbit	2017	Fielded
	UAV	Hermes 90	Israel	Elbit	2009	Fielded
	UAV	Hermes 450	Israel	IAI	Late 1990s	Fielded
	UAV	Hermes 900	Israel	Elbit	2014	Fielded
	UAV	Heron 1	Israel	IAI	2006	Fielded
	UAV	Heron TP	Israel	IAI	2009	Fielded
	UGV	Guardium	Israel	Elbit	2021	Development
	UGV	Rambow	Israel	Meteor Aerospace Ltd.	2017	Development
	UGV	ROOK	Israel	Elbit	2022	Development
	UGV	Avantguarde	Israel	G-NIUS	2010	Fielded
	UGV	Robust	Israel	Elbit	2022	Development
	UGV	Jaguar	Israel	IAI	2021	Fielded
	USV	Protector	Israel	Rafael Advanced Defense Systems	2014	Fielded
	USV	Seagull	Israel	Elbit	2016	Fielded
	UUV	BlueWhale	Israel	IAI	2023	Development
	UUV	HydroCamel II	Israel	BGN Technologies	2017	Development
Australia	***UAV***	PD-100 Black Hornet 2	US	FLIR Systems	2017	Fielded
	UAV	Phantom	China	DJI	2018	Fielded
	UAV	RQ-12 Wasp AE	US	Aeoro Vironment	2015	Fielded
	UAV	ScanEagle	US	Insitu	2007	Fielded
	UAV	CamCopter S-100	Austria	Schiebel	2017	Test
	UAV	RQ-7B Shadow	US	Textron	2011	Fielded
	UAV	MQ-4C Triton	US	Northrop Grumman	2023	Production
	UAV	MQ-9 Reaper	US	General Atomics	2022	Production
	UAV	Aerosonde	Australia	Aerosonde	2003	Fielded
	UAV	Avatar CX1	Australia	Cordarra	2000s	Fielded

	UAV	Hypersonix	Australia	Hypersonix Launch Systems	2021	Development
	UAV	Loyal Wingman	Australia	Boeing Australia	2021	Development
	UAV	Skyborne	Australia	Skyborne Technologies	2021	Development
	UGV	THeMIS	Estonia	Milrem Robotics	2021	Production
	UGV	Jaeger-C	Australia	GaardTech	2022	Development
	UGV	Mission Master CXT	Germany	Rheinmetall	2021	Production
	UGV	Mission Adaptable Platform System (MAPS)	Australia	Praesidium Global	2020	Development
	UGV	Warfighter UGV	Australia	Cyborg Danmics	2021	Development
	USV	Bluebottle USV	Australia	Thales/Ocius	2020	Development
	USV	WAM-W USV	Australia	Queensland University Technology	2020	Development
	USV	Wave Glide	Australia	Boeing/Liquid Robotics	2019	Fielded
	UUV	XLAUV	Australia	Anduril Industries	2022	Development
	UUV	Orca	US	Boeing/Ingalls Industries	2019	Development
Turkey	***UAV***	Black Hornet	US	FLIR Systems	2018	Fielded
	UAV	Serçe-1	Turkey	Aselsan	2018	Fielded
	UAV	Harpy	Israel	IAI	1999	Fielded
	UAV	Kargu (loitering munition)	Turkey	STM	2018	Fielded
	UAV	Bayraktar Mini	Turkey	Baykar	2007	Fielded
	UAV	Bayraktar TB2	Turkey	Baykar Makina	2015	Fielded
	UAV	Bayraktar Kizielma	Turkey	Baykar	2022	Fielded
	UAV	Bayraktar Malazgirt	Turkey	Baykar	2006	Fielded
	UAV	Bayraktar DIHA	Turkey	Baykar	2022	Production
	UAV	BAHA	Turkey	Havelsan	2021	Development
	UAV	Baykus	Turkey	TAI	2004	Fielded
	UAV	Heron 1	Israel	IAI	2010	Fielded

	UAV	Anka (Anka A/B/S variants)	Turkey	TAI	2016	Fielded
	UAV	Aeronautics	Israel	Aeronautics	2012	Fielded
	UAV	Gnat 750	US	GA-ASI	1993	Fielded (Retired?)
	UAV	Baykar Akinci	Turkey	Baykar Makina	2019	Development
	UAV	Kargu-2 (loitering munition)	Turkey	STM	2019	Fielded
	UAV	Songar	Turkey	Asisguard	2019	Fielded
	UAV	Askungur	Turkey	TAI	2019	Fielded
	UAV	Gözcü	Turkey	TAI	2007	Fielded
	UAV	Keklik	Turkey	TAI	2001	Fielded
	UAV	Marti	Turkey	TAI	2003	Fielded
	UAV	IHA-X2 Pelikan	Turkey	TAI	-	Fielded
	UAV	Simsek	Turkey	TAI	2012	Fielded
	UAV	Turna	Turkey	TAI	2001	Fielded
	UAV loitering munition	DELI	Turkey	Titra	2022	Development
	UAV	Karayel	Turkey	Lentatek	2014	Field
	UGV	Haveslan UGV	Turkey	Haveslan	2021	Production
	UGV	Tosun UGV	Turkey	Best Group	2015	Fielded
	UGV	Shadow Cavalry (Rider)	Turkey	FNSS	2021	Development
	UGV	Geko Commander	Turkey	Esestran	2021	Development
	UGV	Kamikaze UGV	Turkey	Esestran	2021	Development
	UGV	Ejder	Turkey	Esestran	2021	Development
	UGV	Naja	Turkey	Haytek	2020	Development
	UGV	Karachulak	Turkey	Altinay	2021	Development
	UGV	Lynx	Turkey	Altinay	2021	Development
	UGV	FCR-360 UGV	Turkey	Arox	2021	Development
	UGV	Teoman	Turkey	Elektoland	2021	Development
	UGV	TMR-I Dinçer	Turkey	Elektoland	2021	Development

	UGV	TMR Ceylan	Turkey	Elektoland	2021	Development
	UGV	TMR II Kutlu	Turkey	Elektoland	2021	Development
	UGV	ACROB	Turkey	Elektoland	2021	Development
	UGV	Zafer	Turkey	Elektoland	2021	Development
	UGV	Hançer	Turkey	Elektoland	2021	Development
	UGV	Bogar	Turkey	Elektoland	2021	Development
	UGV	Etrugrul	Turkey	Aseslan	2021	Development
	UGV	UKAP	Turkey	Aseslan	2021	Development
	UGV	Fedai	Turkey	Best Group	2021	Development
	UGV	Barkan	Turkey	Haveslan/ Tekatran	2021	Development
	USV	SIDA (ULAQ) USV	Turkey	Meteksan Defense	2021	Fielded
	USV	Sancar	Turkey	Havelsan	2022	Development
	USV	SALVO	Turkey	Aesland/ Roketsan	2022	Development

Table 7. Types of UAVs operated and developed by European countries.[1082]

Platform (Origin) - class	Operating country	Operated by	Year of acquisition /latest news	Manufacturer(s)	Developmen t status
Class I UAVs = 0 to 150 kg					
RQ-11 A/B/C Raven (US)	Belgium	Rapid reaction force	2017	AeroVironment	Fielded
	Czech Republic, Italy, Netherlands, Portugal, Spain, Estonia, Lithuania, North Macedonia, Romania, etc.	Army	2008-2013		
	Denmark	Army, Navy	2008-2012		
RQ-20B Puma AE II (US)	Czech Republic, Estonia, Germany, Netherlands, Spain, Sweden, Norway	Army	2013-2019	AeroVironment	Fielded
	Denmark	Army, Navy	2012		
RQ-12A Wasp Block IV (US)	France	Special Forces	2014	AeroVironment	Fielded
	Spain, Sweden, Norway	Army	2019		
Scan Eagle (US)	Czech Republic, Poland, Lithuania, Romania	Army	2015-2017	Insitu	Fielded
	Spain, Netherlands	Army, Navy	2012-2014		
RQ-21 Blackjack (US)	Netherlands, Poland	Army	2018	Insitu	Fielded
T-Hawk (US)	UK	Army	2010	Honeywell	Fielded
Desert Hawk Mk3 (US)	UK	Army	2014	Lockheed Martin	Fielded
Phoenix 30 (US)	Bulgaria, Romania	Army	2014	UAV Solutions	Fielded
Orbiter (Israel)	Finland, Poland, Switzerland, Croatia, Serbia	Army	2014-2018	Aeronautics Defense	Fielded
MicroFalcon (Israel)	Poland, Slovakia	Training	2009-2012	Innocon	Fielded

[1082] Table made by authors: *Sources*: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020.; Gettinger, Dan. “The Drone Databook”, *The Center for the Study for the Study of the Drone at Bard College*, 2019.; List of unmanned aerial vehicles, *Wikipedia,* (Accessed on 08.12.2022), Interviews and others.

Skylark (Israel)	Czech Republic, Croatia, Slovakia	Army	2007-2012	Elbit	Fielded
	France, Sweden	Special Forces	2007-2015		Fielded
Spy Ranger (France)	France	Special Forces, Army	2019	Thales	Fielded
3S (France)	France	Army	2019	Drone Protect Systems	Fielded
Mavic (China)	France, Finland, Portugal	Army	2018	DJI	Fielded
Phantom 3&4 (China)	Germany	Marines	2016	DJI	Fielded
Inspire (China)	Lithuania	Army	-	DJI	Fielded
NX70 (France)	France	Army	2019	Novadem	Fielded
Tracker (France)	France, Austria	Army	2006	EADS Cassidian	Fielded
IT180-3EL-1 (France)	France	Army	2012	ECA Group, Infotron	Fielded
UX11 (France)	France	Army	2019	Delair	Fielded
AVE-D Petit Duc (France)	France	Army, Special Forces	2000	Dassault	Fielded
LA100/200/300	France	Army	2005-2017	Lehmann Aviation	Fielded
MIKADO (Germany)	Germany	Army, Marines	2019	AirRobot	Fielded
Guardion (Germany)	Germany	Army, Special Forces, Police	2017	Guardion Technology	Fielded
ALADIN (Germany)	Germany, Netherlands	Army, Marines	2003	EMT	Fielded
Strix-C (Italy)	Italy	Air Force	2009	Alpi Aviation	Fielded
Strix-DF (Italy)	Italy	Navy	-	Alpi Aviation	-
RQ-24A Sixton (Italy)	Italy	Army	2008	Selex-ES	Fielded
Alcotan (Spain)	Spain	Navy	2016	Unmanned Solutions	Fielded
Alpha 800 (Spain)	Spain	Army	2018	Alpha Unmanned Solutions	Fielded
Condor (Spain)	Spain	Air Force	2018	Optimum Solutions	Fielded
SIVA (Spain)	Spain	Air Force	2006	INTA	Fielded
Atlantic (Spain)	Spain	Army	2017	SCR	Fielded
Tucan (Spain)	Spain	Army, Air Force	2018	SCR	Fielded
Mantis EQF (Spain)	Spain	Army	2019	Indra & BAE Systems	Fielded
Orbiter 2B (Israel)	Finland, Ireland	Army	2016	Aeronautics	Fielded
Orbiter 3 (Israel)	Spain, Poland	Army	2017	Aeronautics	Fielded
PD-100 Black Hornet (NOR/US)	France, Spain, UK,	Special Forces	2017-2019	FLIR	Fielded

	Netherlands, Poland				
SkyRobot FX/20/450 (Norway)	Norway	Army, Special Forces	-	Robot Aviation	Fielded
SkyWatch Huginn X2(Denmark)	Spain	Army, Navy	2016	Sky-Watch	Fielded
Fulmar X (Spain)	Spain	Army, Navy	2017	Thales Espana	Fielded
Warmate (Poland)	Poland, Ukraine	Army (loitering munition)	2017	WB Electronics	Fielded
FlyEye (Poland)	Poland, Ukraine	Army, Special Forces	2013	WB Electronics	Fielded
Orlik PGZ-19R (Poland)	Poland	Army	2021	WZL-2	Production
PR-5 Wiewior plus (Poland)	Poland	Army, Special Forces	2010	PRZ	Fielded
Penguin-C (Latvia)	Latvia	Army	2019	UAV Factory	Fielded
AR4 Light Ray (Portugal)	Portugal	Army	2011	Tekever	Fielded
SACT Boreal 5 (Romania)	Romania	Army	-	Military Equipment and Technologies Research Agency	-
Bramor (Slovenia)	Slovenia, Italy	Army	2014	C-Astral	Fielded
Shepherd-Mil (Spain)	Spain	Army	2022	Arquimea	Development
Class II UAVs = 150 to 600 kg					
Camcopter S-100 (Austria)	Belgium, France, Norway, Italy, Russia	Navy	2012-2015	Schiebel	Fielded
RQ-5 Hunter (Israel)	Belgium	Air Force	2015	TRW	Retired
Ranger (ISR/CH)	Finland, Switzerland	Air Force, Army	2003	RUAG Aerospace	Retired
Patroller (France)	France	Army	2022	Safran	Fielded
AVE-D Moyen Duc (France)	France	Air Force, Navy	2004	Dassault	Fielded
CK50-T (France/ Taiwan)	France	Air Force, Navy	2023	GEOSAT Aerospace and Technology chair & Cavok UAS	Development
Skeldar V-200 (SWE/CH)	Germany, Spain, Sweden	Navy	2019	Skeldar	Fielded
Luna X-2000 (Germany)	Germany	Army	2000	EMT	Fielded
Sagitta (Germany)	Germany	Air Force	2017	Airbus	Development
KZO (Germany)	Germany	Army	2005	Rheinmetall	Fielded
Falco ES (Italy)	Italy	Army, Air Force	2009	Leonardo	Fielded

Pegasus II Block I (Greece)	Greece	Air Force	2005	Hellenic Aerospace Industry	Fielded - Retired
Searcher (Israel)	Spain, Cyprus	Army	2002-2004	IAI	Fielded
Q-SLAM-40 (Spain)	Spain	Army	2022	Arquimea	Development
RQ-7 Shadow (US)	Sweden, Romania	Air Force	2011	AAI	Fielded
	Italy	Army	2014		Fielded
Hermes 450 (Israel)	UK	Army	2007	Elbit	Fielded
HERTI (UK/US)	UK	Air Force	2008	BAE Systems	Fielded
Mantis (UK)	UK	Air Force	2009	BAE Systems	Fielded
Watchkeeper 450 (UK)	UK	Army	2014	Thales UK, Elbit	Fielded
Malloy T150 (UK)	UK	Army, Marines, Air Force	2021	Mallow Aeronautics	Fielded
Taranis (UK)	UK	Air Force	2012	BAE Systems	Development
Demon (UK)	UK	Air Force	Mid-2010s	BAE Systems	Fielded
PHASA-35 (UK)	UK	Air Force	2020	BAE Systems	Development
Novel Air Concept (UK)	UK	Air Force	-	BAE Systems	Development
Qinetiq Mercator 1 (UK/Belgium)	UK, Belgium	Air Force	2012	VITO	Fielded
SA03 Flyox (UK/Spain)	UK, Spain	Air Force	2020	Singular Aircraft	Production
Zephyr (UK)	UK	Air Force	2017	Airbus	Development
Class III UAVs = more than 600 kg					
MQ-9 Reaper (US)	France, Italy, Netherlands, Spain, UK, Greece	Air Force	2007-2012	GA-ASI	Fielded
Mojave (UK)	UK	Navy	2023	GA-ASI	Development
MQ-1 Predator (US)	Italy	Air Force	2004	GA-ASI	Retired
MQ-9B SkyGuardian (US)	Belgium, UK	Air Force	2017	GA-ASI	Fielded
Heron (Israel)	Germany, Greece	Air Force	2010-2012	IAI	Fielded
Heron TP (Israel)	Germany	Air Force	2019	IAI	Fielded
Harfang (France/Israel)	France	Air Force	2008-2018	IAI, EADS	Fielded
Talarion (France/Israel)	France	Air Force	2018	IAI, EADS	Development

Aarok (France)	France	Air Force	2023	Turgis & Gaillard	Development
HammerHead (Italy)	Italy	Air Force	-	Piaggio Aerospace	-
Hermes 900 (Israel)	Switzerland	Air Force	2019-2022	Elbit	Fielded
RQ-5 Hunter-B (Israel)	Belgium	Air Force	2001	TRW	Fielded
RQ-4 Global Hawk (US)	NATO	Air Force	2019	Northrop Grumman	Production
Barracuda (Germany/ Spain)	Germany, Spain	Air Force	2006	EADS	Fielded
Sirtap (Spain	UK, Spain, Colombia	Air Force, Army	2023	Airbus	Development
Sky X (Italy)	Italy	Air Force	2008	Alenia Aeronautica	Fielded

Table 8. Types of UGVs operated and developed by the studied European countries.[1083]

Type of robotics	Name	Country of origin	Purpose	Manufacturer	Latest news (year)	Development status
			UGVs			
UGV	iMUGS	EU project, Estonia	ISR, combat	Milrem Robotics	2022	Development
UGV	Combat Unmanned Ground Systems (CUGS)	EU (EDA)	Combat, system of systems	EDA, national agencies	2023	Development
UGV	Titan	UK	Multi-purpose	Qinetiq, Milrem Robotics	2021	Development
UGV	Viking	UK	Multi-purpose, combat	Horiba Mira	2022	Development
UGV	T7	UK	Demining	L3 Harris Technologies	2021	Fielded
UGV	Mission Adaptable Platform System (MAPS)	UK, Australia	Multi-purpose	Praesidium Global	2019	Development
UGV	Heavy Unmanned Ground Vehicle (HUGV)	UK	Multi-purpose, combat	Elbit, DSTL, Milrem, Rheinmetall	2023	Development
UGV	SMINEX Tender	France	Demining	ECA Group	2019	Development
UGV	Iguana	France	Demining	ECA Group	2020	Development
UGV	Cameleon LG E	France	Demining, ISR	ECA Group	2019	Fielded
UGV	Optio-X20	France	Combat, support, ISR	Nexter	2021	Development
UGV	Ultro	France	Support, CBRN	Nexter	2021	Development

[1083] Table made by authors. Sources: Global Military Robotic and Autonomous (RAS) Systems Market, *BIS Research*, Paseo Padre, California, October 2020; Nexter UGVs tested by French army in defensive and offensive actions, *Army Recognition*. (Accessed on 18.04.2023); Rüstungsfirmen stellen unbemannte Militärfahrzeuge vor, *Deutscher Bundeswehrverband,* (Accessed on 12.04.2023); Dstl showcases autonomous future for army logistics, *Gov.UK*, (Accessed on 14.04.2023); Peruzzi, Luca. I programmi di acquisizione ed ammodernamento dell'Esercito Italiano, *AnalisiDifesa*. (Accessed on 19.04.2023); Patria Heavy Unmanned Ground Vehicle (UGV), *MilitaryLeak*. (Accessed on 19.04.2023); MSPO 2022: PGZ from Poland displays Perun autonomous reconnaissance and combat UGV, *Army Recognition*. (Accessed on 19.04.2023); Thoresen, Marius et al. "Path Planning for UGVs based on Traversability Hybrid A", *IEEE Robotics and Automation Letters*, 2021.; THeMIS Hybrid Unmanned Ground Vehicle, *Army Technology*. (Accessed on 20.04.2023), Interviews and others.

UGV	Nerva	France	Demining, ISR	Nexter	2021	Development
UGV	Phobos	France	Multi-purpose, ISR	Nexter	2023	Development
UGV	Mission Master	Germany	Multi-purpose	Rheinmetall	2023	Fielded
UGV	Stamina	Germany France	Multi-purpose, combat	Institut Saint-Louis	2021	Development
UGV	Ziesel	Germany	Multi-purpose	Diehl, Hentschel Systems GmbH	2022	Development
UGV	Wiesel	Germany	Combat	Rheinmetall	2022	Development
UGV	TRP-2	Italy	Combat, ISR, support	Forza NEC	2020	Development
UGV	TRP-3 NEC	Italy	ISR	Forza NEC, Leonardo	2020	Development
UGV	Linca 2 VTML	Italy	Multi-puprose	Iveco	2022	Development
UGV	Viking	Italy	Multi-purpose	MIRA & Iveco	2023	Development
UGV	Valkyrie	Spain	Combat, support	SASCorp	2021	Development
UGV	Patria UGV	Spain, Neth., Belgium, Finland	Multi-purpose, combat	Patria AMW	2020	Development
UGV	Perun	Poland	Combat, ISR	PGZ	2022	Development
UGV	Lewiatan	Poland	Multi-purpose	-	-	-
UGV	Taero	Poland	Transport, support	WITPiS	2022	Development
UGV	Hunter	Poland	ISR, patrol	PIAP	2020	Development
UGV	RPP	Poland	Demining, support	PIAP	2021	Fielded
UGV	Olav	Norway	Transport, Multi-purpose	Ranger, FFI	2021	Development
UGV	THeMIS	Estonia	Multi-purpose, combat	Milrem Robotics	2022	Fielded
UGV	Type-X	Estonia	Combat	Milrem Robotics	2022	Development
UGV	Robotic Combat Vehicle (RCV)	UAE, Estonia	Combat	EDGE Group & Milrem Robotics	2023	Development

Table 9. Types of UMSs operated and developed by the studied European countries.[1084]

Type of robotics	**Name**	**Country of origin**	**Purpose**	**Manufacturer**	**Latest news (year)**	**Development status**
			UMSs			
USV	Proteus	UK	ISR, ASW, MCM	BAE Systems	2021	Development
USV	SeaTrac	UK, US	MCM, ASW, Tracking	Blueprint	2021	Development
USV	Bluefin-21	UK	ISR, ASW	Bluefin Robotics	2022	Fielded
USV	ARCIMS	UK	MCM, ASW, support	Atlas Elektronik UK	2020	Development
USV	Halycan	UK	MCM, ASW, support	Thales	2020	Development
USV	REAV-16/40	UK	Multi-purpose, ISR	Hydro-Surv	2021	Development
USV	MMCM (SLAMF)	UK, France	MCM, ASW	Thales	2021	Development
UUV	Project Cetus (MANTRA)	UK	ASW, support	M Subs	2022	Development
UUV	Alista 27 (Dorade)	UK	Multi-purpose, ISR	ECA Group	2021	Fielded
UUV	REMUS 600/620	UK, Sweden	MCM, ASW, ISR	Huntington Ingalls Industry	2022	Development
UUV	SeaCat	UK	MCM, ASW	Atlas Elektronik UK	2022	Development
UUV	Autosub-6000	UK	ISR, Multi-purpose	Autosub, National Oceanography Centre	2019	Fielded
UUV	Herne XLUUV	UK	Multi-purpose	BAE Systems	2022	Development

[1084] Table made by authors. Sources: Global Military Robotic and Autonomous (RAS) Systems Market, BIS Research, Paseo Padre, California, October 2020; *Covert Shores*. (Accessed on 12.04.2023); Unmanned Surface Vehicles (USVs): Defence and Technology Trends, *Naval Technology*. (Accessed on 21.04.2023); Bauer, Anne. Naval Group promet un drone sous-marin dans quatre ans, *Les Echos*. (Accessed on 17.04.2023); Sutton, H I. World's Largest Submarine Drone Being Built In Germany, *Naval News*. (Accessed on 21.04.2023); Mini-Ranger and U-Ranger USVs, *L3Harris*. (Accessed on 21.04.2023); Navantia Integrates Unmanned Vehicles On Spanish Navy Vessel, *Naval News*. (Accessed on 18.04.2023); Fugro's Uncrewed Surface Vessel Provides TAQA with Safer and More Sustainable Offshore Inspections, *Fugro*. (Accessed on 19.04.2023); Kalinowski, Arkadiusz, and Józef Małecki. "Polish USV 'EDREDON' and Non-European USV: A Comparative Sketch." *Journal of Marine Engineering & Technology* 16, No. 4, February 2017, 416–19.; Kongsberg Maritime: New Norwegian Autonomous Shipping Test-Bed Opens, *Ocean News*. (Accessed on 11.04.2023); Swedish Navy Tests Saab Enforcer III USV During Exercise, *Naval News*. (Accessed on 15.04.2023); Medium Size Semi-Autonomous Surface Vehicle (M-SASV), *PESCO*; and others.

USV	DriX	France	MCM, ASW, ISR	iXblue	2018	Development
USV	Inspector 125	France	MCM, ASW, ISR	ECA Group	2019	Production
USV	Steren Du	France	Multi-purpose	Naval Group	2022	Development
UUV	Aquasmart	France	MCM, ISR	ECA Group	2020	Development
UUV	SIRENE	France	ISR, ASW	RTSYS	-	Development
UUV	A18-M	France	ISR, ASW	ECA Group	2022	Fielded
UUV	D-19T	France	ISR, ASW, electronic warfare	Naval Group	2020	Production
UUV	SEMA	France	Combat, ASW	RTSYS	2021	Development
UUV	Oceanic Underwater Drone	France	Multi-purpose	Naval Group	2021	Development
UUV	Unmanned Combat Underwater Vehicle (UCUV)	France	ISR, combat	Naval Group, DGA	2023	Development
UUV	Modifiable Underwater Mothership	Germany	Multi-purpose	Thyssen-krupp Marine Systems	2023	Development
UUV	Minelaying XLUUV	Germany	MCM, ISR	Thyssen-krupp Marine Systems	2023	Development
UUV	Hunter-killer	Germany	ASW, ISR	Thyssen-krupp Marine Systems	2023	Development
UUV	Scout	Germany	ISR	Thyssen-krupp Marine Systems	2023	Development
USV	U-Ranger	Italy	Multi-purpose	Calzoni, LH3 Harris	2021	Development
USV	Mini-Ranger	Italy	ISR, patrol	Calzoni, LH3 Harris	2021	Development
USV	Permeare	Italy	-	CNR-INSEAN	-	Development
UUV	Recon-UV	Italy	-	MDM Team	2022	Development
USV	Vendaval (RAL 900 ZSF)	Spain	ISR, C4	Navantia System, AISTER	2019	Development
USV	Viento	Spain	Multi-purpose	Navantia System	2020	Development
UUV	UXV	Spain	Multi-purpose	Navantia System	2023	Development
USV	Fugro	Neth.	ISR	Blue Essence	2021	Production
USV	Tender Shark	Neth.	ISR, cleaning	RanMarine	2023	Production

USV	Hornet	Poland	Multi-purpose	Gdansk University of Technology	2022	Fielded
USV	EDREDON	Poland	Combat, ISR, MCM	Polish Naval Academy	2021	Development
UUV	Katfish	Poland	MCM	Kraken Robotics	2020	Fielded
USV	Sounder	Norway	ISR	Kongsberg	2020	Fielded
USV	Mariner/X	Norway	ISR	Maritime Robotics	-	Production
USV	Otter	Norway	ISR	Maritime Robotics	-	Production
USV	Odin	Norway	Multi-purpose	Kongsberg	2020	Fielded
USV	XO-16	Norway	MCM, ASW, ISR	Kongsberg	2022	Development
UUV	Hugin	Norway	MCM, ASW, ISR	Kongsberg	2022	Development
USV	Bonefish	Sweden, Indonesia	Multi-purpose, combat	SAAB, North Sea Boat	2015	Development
USV	Enforcer III	Sweden	ISR, support	SAAB	2022	Development
USV	Piraya	Sweden	Stealth, ISR	SAAB	2021	Development
USV	SAM 3	Sweden	MCM	SAAB	2021	Development
USV	CB-90 Optionnally Manned USV	Sweden	Combat, multi-puprose	SAAB	2022	Development
USV	Medium Size Semi-Autonomous Surface Vehicle (M-SASV)	Estonia	Multi-purpose	PESCO	2022	Development
USV	170M-Detector	UAE, Estonia	Multi-purpose	EDGE Group	2023	Development

Recommendation 3: *Legal rationale – Encourage innovation by exploiting RUAG MRO as a quasi-in-house procurement body for the Swiss armed forces.*

As described in a piece of legal advice, *"(…) RUAG MRO is deemed to be an internal service provider as long as the prerequisites of the quasi-in-house exception pursuant to "Strategic objectives of the Federal Council for BGRB Holding AG for the period 2020 to 2023", point 3.3, al. 1.2 are met (control by the Confederation and at least 80 percent of turnover from orders placed by the Confederation)."*[1085] In this regard, and in accordance with EU procurement law (to which Switzerland is tied, as per the Bilateral Agreements[1086]) and the case law of the European Court of Justice, procurement law cannot be applied if the so-called "Teckal criteria" (respect of both the "80-20 rule" and the existence of meaningful control by the state on a private service provider exists) is at play.[1087] Thus, according to the jurisprudence of the "Teckal criteria", in order to escape the obligation to apply the law on public procurement and to use RUAG MRO as a quasi-internal purchasing body, the Confederation's relationship with RUAG MRO must meet the following two conditions:

1) Respect of the "80-20" rule, meaning that RUAG MRO does not do more than 20% of its overall turnover with third parties, other than the Confederation

2) Meaningful direct/indirect control of RUAG MRO by the Swiss Confederation

Point 1) is provided for by law, in the "Strategic objectives of the Federal Council for BGRB Holding AG for the period 2020 to 2023", point 3.3, al. 1.2, *"The Federal Council expects the financial holding company to ensure that: 1. the RUAG MRO Holding AG sub-group and the companies it directly or indirectly controls (…) ensure that sales from third-party markets (excluding real estate) do not exceed 20% of total sales;"*[1088] Therefore, it can be considered that RUAG MRO is expected to observe and respect the "80-20 rule", and that this condition is fulfilled.[1089]

Point 2) relates to the requirement for the Swiss Confederation to have control over RUAG. Since the Swiss Confederation owns - directly or indirectly - 100% of RUAG MRO's shares, this means that it exercises exclusive control.[1090] In other terms, no private party possesses a share or interests in the service provider, meaning that the Confederation is the only body that takes decisions and manages RUAG. In addition, the legal control of RUAG MRO by the Confederation is defined in Articles 2, 3 and 4 of the Federal Law on Armaments Companies of the Confederation (LEAC).[1091] Therefore the second condition is fulfilled as well.

Consequently, as stated in the piece of legal advice, *"The quasi-in-house exception is not limited to certain types of contracts. (…) the Confederation may procure services from RUAG MRO without observing public procurement law."*[1092] As long as the two requirements of the

[1085] Jäger, Christophe and Geiger, Thomas. "Gutachten – Beschaffungsrechtliche Fragen zur RUAG MRO", *Kellerhals Carrard*, 22 April 2020.: 3.
[1086] Abkommen zwischen der Schweizerischen Eidgenossenschaft und der Europäischen Gemeinschaft über bestimmte Aspekte des öffentlichen Beschaffungswesens, *Schweizerische Eidgenossenschaft*, 21 Juni 1999, SR 0.172.052.68.: 1-3.
[1087] Case C-107/98 "Teckal", European Court of Justice, 11 November 1999.: 8154.
[1088] Objectifs stratégiques du Conseil federal assignés à BGRB Holding SA (entreprise d'armement de la Confédération) pour la période 2020 à 2023, *Confédération Suisse*, 23 Octobre 2019, 2019-3822. : 925.
[1089] Das Geschäftsjahr 2021 im Überblick, RUAG MRO, 2021.: 9.
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“Teckal criteria” are respected, the Confederation can legally use RUAG MRO as a quasi-in-house procurement body, without having to observe the public procurement law.

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