EUROPEAN
DEFENCE
AGENCY

ENHANCING EU MILITARY CAPABILITIES BEYOND 2040

Main findings from the 2023 Long-Term Assessment of the Capability Development Plan

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Isdefe, September 2023

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FOREWORD

By Jiří Šedivý,
EDA Chief Executive

"Europe's future security depends on a more robust and agile response. By working together to develop stronger and more credible military capabilities, the EU can be proactive in safeguarding its security, asserting its autonomy, and ensuring the safety and well-being of its citizens. This will require a deep commitment to collaboration and innovation, as well as a willingness to embrace new technologies."

Jiří Šedivý,
EDA Chief Executive

Fifteen years since its inception, the Capability Development Plan (CDP) remains the primary reference for European Union defence planners, providing them with priorities and opportunities to collaborate to improve EU defence capabilities.

While the adoption of the EU's Strategic Compass underlined the need for full-spectrum capabilities, the return of war to Europe with Russia's invasion of Ukraine has made them mandatory. The Russian war of aggression is a defining event from a strategic and military perspective. The revision of the CDP, launched by Member States in 2022, reflects the lessons drawn from in the war in Ukraine. The technological perspective is a vital part of this.

As we try to envisage what threats we might face in 2040, one thing is certain: maintaining technological supremacy through defence innovation is a strategic necessity. It is therefore a key consideration within the long-term assessment of the CDP. This long-term strand identifies future strategic factors, related future capability requirements, technological challenges, and opportunities to be considered.

We have already witnessed the integration of emerging and disruptive technologies (EDTs) on the battlefield in Ukraine. Even if their real impact has yet to be seen, EDTs must be considered as an essential element of future capability requirements.

The CDP's Long-Term Capability Assessment explores the future capability trends and assesses the standard military tasks over a timeline of 20 years or more years' timeframe. The aim is to provide EU Member States' armed forces with a wide span of possible factors that may impact future capability requirements from 2040 and beyond.

This short publication provides a summary of the factors that will be taken into consideration. It also offers a valuable insight into the CDP, whilst also identifying strategic challenges which are likely to shape the operational environment for EU Armed Forces beyond 2040.

No one can know for sure what future conflicts may arise, but we will have capabilities at the ready.

THE CAPABILITY DEVELOPMENT PLAN

INTRODUCTION

Since 2008, the European Defence Agency (EDA) has been producing a Capability Development Plan (CDP) to address security and defence challenges. It looks at future security scenarios and makes recommendations about the capabilities European militaries may need to react to a variety of potential developments while maintaining the initiative and freedom of action. The CDP is a comprehensive planning method providing a picture of European military capabilities over time. It can be used by Member States' defence planners when identifying priorities and opportunities for cooperation.

Since 2008, the European Defence Agency has been regularly updating its Capability Development Plan (CDP) in close cooperation with its Member States and with the active contributions of the EU Military Committee (EUMC) and the EU Military Staff (EUMS).

The purpose of the periodic CDP revision is to provide a full and up-to-date capability picture that supports decision-making at the EU and national level regarding defence capability development by addressing the current security challenges from a strategic standpoint. The overall objective is to increase coherence between Member States' defence planning and encourage European cooperation by looking together at future operational needs and defining common EU Capability Development Priorities. The CDP revision benefits from several inputs such as the Helsinki Headline Goal Process, studies on long-term trends, lessons from operations and information on national plans and programmes.

The CDP is developed using four different strands of inputs, all validated by Member States. All strands contribute to identifying the EU Capability Development Priorities.

Through a comparison of military requirements in the Common Security Defence Policy (CSDP) framework and Member States' declared capabilities, the CDP includes the CSDP shortfalls and the associated operational risks. In addition, from a short-term perspective, the CDP considers lessons identified from operations by analysing capability development considerations from recent military experience in the field. These two short-term inputs are provided by the EU Military Committee with the support of the EU Military Staff.

For a medium-term perspective, EDA assesses the potential for cooperation by analysing activities where Member States intend to engage between 2023 and 2040. The main sources are the EUCLID (EU Collaboration in Defence) Database and national plans and programmes. The Coordinated Annual Review on Defence (CARD) along with ad-hoc and other reports contribute to completing the picture for each capability.

In its longer-term perspective, the CDP offers an analysis of long-term capability trends in the next 20 or more years and potentially associated requirements for each capability. This goal is achieved by linking long-term technology perspectives to future operational environments, resulting in long-term requirements and related R&T needs.

The present document reflects the outcome of the 2023 long-term strand revision, referred to as "Strand B". It identifies key future strategic environment factors, future capability areas' requirements and technology fields that Member States need to focus on to support the development of defence and security capabilities in the timeframe of in the next 20 years or more.

[1] A military capability is the ability to perform actions in order to achieve effects. It is defined by minimum requirements along identified lines of development (DOTMLPFI - Doctrine and Concept, Organization, Training, Material, Leadership, Personnel, Facilities, and Interoperability).

CDP STRAND B METHODOLOGY

To elaborate on this long-term capability assessment, the EDA has initiated an evaluation process with the support of Member States (MS). In order to ensure a methodologically sound assessment, EDA has also commissioned Isdefe to provide support throughout the entire process. The timeframe established for the assessment, according to the CDP short, mid and long-term periods, is from 2040 onwards.

The assessment process consisted of three main activities. Firstly, an analysis of the future operational context was conducted, considering worldwide geopolitical and socio-economic macro trends, including possible security and environmental challenges. Secondly, possible long-term operational scenarios were developed and finally, two tabletop exercises (TTX) were conducted to extract preliminary defence capability requirements findings.

The first mentioned activity was based on a comprehensive review and assessment of official publications and documents, from EU, MS and NATO relevant entities, referring to **strategic and technological foresight in the long term** and the identification of specific military tendencies in 2040 and beyond.

Scenarios development was guided by identified general trends, set at a strategic-operational level in the decade of 2040, considering threats and capabilities provided by the relevant foresight analysis, while remaining credible and realistic. The scenarios covered the full spectrum of military capabilities in all domains.

Finally, **two tabletop exercises** (TTX) were designed to produce rich and fruitful discussions about the relevance and trends of military capabilities demanded for 2040 and beyond among a group of experts including defence capability planners, technology experts and foresight analysts from MS, EDA, EUMS, EUMC and NATO.

Each of the two scenarios comprised fictitious allies, adversaries, other state, and non-state actors, on a representative albeit not real geographical scene and a sequence of actions comprising the full spectrum of conflict. Military capabilities demanded in 2040 and beyond were assessed during the TTXs identifying technological impact, future importance of generic military tasks and capability trends.

The present document constitutes a concise summary of this evaluation and should not be regarded as exhaustive, but rather as an overview of its principal findings.

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private fun initWebVie
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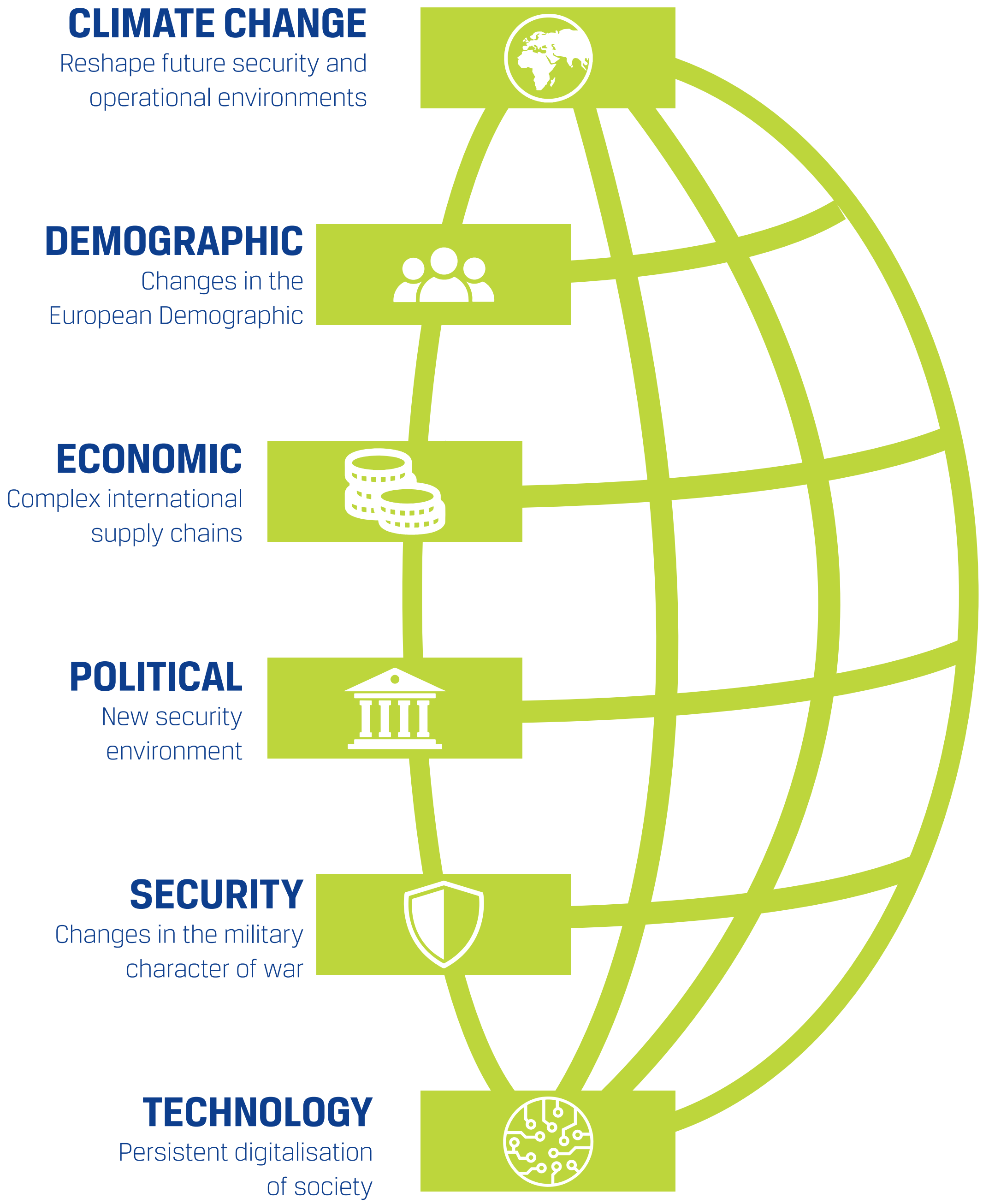
GLOBAL FUTURE STRATEGIC FACTORS

As the first phase of the long-term capability assessment process, an analysis of the main factors that will shape the strategic context in the considered timeframe has been conducted. This analysis was based on the reference foresight studies carried out by various Member States, as well as by the EDA itself for future technologies, and by NATO through the Strategic Foresight Analysis.



CLIMATE CHANGE
Reshape future security and
operational environments

DEMOGRAPHIC
Changes in the
European Demographic

ECONOMIC
Complex international
supply chains

POLITICAL
New security
environment

SECURITY
Changes in the military
character of war

TECHNOLOGY
Persistent digitalisation
of society

CLIMATE CHANGE

The effects of climate change, pollution, policies to reduce carbon emissions, and competitiveness for raw materials will play a significant role in the socio-economic and security landscape of 2040 and beyond.

Climate change has been increasing at an accelerated pace in recent decades, and its effects could be even more challenging in the long term, including the rise of sea levels, extreme temperatures, the opening of the Arctic, and natural disasters. These extreme conditions will **reshape future security and operational environments** in many ways, implying the need to improve military capabilities to ensure the ability to operate in more hazardous environments.

Societies all over the globe are creating policies and roadmaps to drastically reduce carbon emissions and pollution in the coming decades, which are currently posing numerous challenges for the industrial and technology sectors. European companies must be able to achieve **sustainable development goals** while maintaining their competitive advantages over other companies worldwide.

In addition, the competition for certain critical resources will be heightened by the effects of climate change. Severe climatic conditions will make **water, agricultural land, and certain raw materials increasingly scarce**. This may be used by adversary states and other actors to affect supplies of basic resources and goods in order to destabilise economies and promote unrest among the population. Moreover, these extreme conditions, along with pollution and toxic wastes, could increase the risk of new health threats to the world population, which could also be induced intentionally.

Climate change could become a possible driver for all remaining trends, since the consequences may be exploited intentionally to produce significant security challenges. Therefore, the pace and availability of geo-engineering technologies and other advances in this sense might become critical.

Expected climate change impact

Reshape future security and operational environments

Sustainable development goals maintaining competitiveness

Certain raw materials increasingly scarce

Climate change could become a possible driver for all remaining trends, since the consequences may be exploited intentionally producing significant security challenges.

DEMOGRAPHIC

Europe's demographics in 2040 will be different to today's, trends show, with a significant impact on pollution, security and the economy.

The social structure will suffer great changes as a consequence of population aging and contracting, the **declining power of the middle class**, the **social turmoil** and **uncontrolled migration**. These instabilities and asymmetric demographic changes will also cause major challenges for many economies and government policies.

Another great risk associated with the increased population density and globalisation is the appearance of new threats for public health. As the COVID-19 pandemic has shown, the demographic and economic consequences of contagious diseases will grow exponentially in a society that is increasingly interconnected and concentrated in highly urbanized areas. Health threats could even be used as a weapon by adversary states and terrorist groups in order to promote unrest among European states.

The labour market in Western societies is also expected to change in the long term with **increasing employment disruption**. As most activities will tend to concentrate in large cities, migration from rural areas and other countries is expected to produce further **expansions in urban areas**, resulting in megacities. The increase in population and migration may also result in ethnic, religious, and cultural tensions in certain regions.

From a social point of view, an increasing degradation of social cohesion is foreseen, along with growing social polarization. Factors such as nationalism, economic inequality, or religious identity could undermine the trust and legitimacy of democracy. Moreover, it is expected that the population will acquire a greater sensitivity to international conflicts, tensions, and casualties, playing a more active and important role in conflicts' development and affecting the decision-making processes of the armed forces. This situation will make it more important than ever to create a social conscience around defence in European countries.

Declining power of the middle class

Expansions in urban areas

Uncontrolled migration

Increasing employment disruption

The social structure will suffer great changes as a consequence of population aging and contracting, the declining power of the middle class, the gender imbalance and uncontrolled migration.

ECONOMIC

The economic trends point to various factors that could increase instabilities in Western societies, such as the lack of natural resources, economic and social inequities, and the **increased competitiveness for global commons**.

The availability of resources is increasingly affected by **complex international supply chains** for key components (such as microchips), the **scarcity of critical resources** (such as rare earth minerals), and geopolitical relationships. The increasing demand and dependence on these resources will entail many risks and challenges, such as increased pressure on food and water security, scarcity of critical raw materials, infrastructure fragility or over-exploitation of natural resources.

From a social point of view, economic and social inequity, including rising inequality and slow economic growth, pose significant challenges to social cohesion and fragmented societies. Economic instability will increase migrations and differences between countries in terms of employment opportunities, ageing, and economic growth.

New technologies, along with higher dependencies on key components, will also have major impacts on employment, demanded skills, and economic opportunities. Establishing a strong technological and industrial base in Europe will become even more necessary in reducing key component dependencies, guaranteeing the security of supply, increasing economic opportunities for citizens, and ensuring a stable economic growth. Likewise, the European defence technology and industrial base will need to maintain **investment in critical technologies** necessary to develop strong military capabilities.

Increased competitiveness
for global commons

Complex international
supply chains

Scarcity of
critical resources

Investment in
critical technologies

New technologies, along with the higher dependencies on key components, will also have major impacts on employment, demanded skills, and economic opportunities.

POLITICAL

Changing the world balance of power

Shift of power towards the private sector

Widespread of misinformation

Lack of trust in governments and institutions

From a political perspective, many arising changes in the global order will shape the future security and operational environment. The interdependence of resources is increasingly conflictual, shaping a multipolar international order with greater competition and power transition between countries, which also intensify global instability. Likewise, instability around the world could also be a major factor in this **new security environment**, such as the complex situation in Africa and the Middle East, and the increasing tensions in the Asia-Pacific region.

A general trend worldwide is that democratic societies face a growing **lack of trust in governments and institutions**, as well as heightened social polarization due to economic inequalities, increased radicalisation, and ethnic, cultural, and political conflicts. This greater public discontent can pose a challenge to the rule of law in Europe, which could be fuelled by factors such as the impact of new technologies in society, the spread of misinformation, rights inequality, and the struggle over ever scarcer natural resources.

Another trend tis the **increasing relevance of non-state actors**. Western states have gradually seen their leadership over technological development decline, which plays an increasingly important role in society, the global economy, and political power. The increasing power of private companies due to this technological dependence could contribute to the loss of autonomy by governments. These would see their decision-making capacities constrained and could lose their monopoly of force in the long term, which is one of the pillars of national security.

The Russian war of aggression against Ukraine has brought to light a latent reality in which conventional conflicts are still in force, but without forgetting the hybrid component and the development of actions in grey zones. The return to power politics leads some countries to act in terms of historical rights and zones of influence, rather than adhering to internationally agreed rules and principles and uniting to promote international peace and security. The world is becoming less free with human rights, human security, and democratic values under attack – both at home and abroad, therefore a competition of governance systems accompanied by a real battle of narratives is observed and might shape the future strategic environments.

The growing interdependence of resources between western and eastern states is changing the world balance of power, which is increasingly tilting towards Asia and giving rise to a multipolar international order with greater competition.

SECURITY

The widening array of risks and threats, including the increasing use of social engineering and misinformation, the increasing threat of **terrorism and organized crime**, and the **changes in the military character of war** are expected to pose an ever more direct threat to societies and population.

The spectrum of risks will be more expansive than ever due to the new technologies and new tactics used by potential adversaries, including those related to the cyber domain, unconventional tactics used in hybrid conflicts, new **biological weapons, software-defined warfare,** or cognitive warfare. This expansion of threats could further erode human security, while posing new ethical challenges, extending crises and conflicts, and creating new vulnerabilities.

Social engineering and misinformation are expected to play a major role in future conflicts, turning possibly society itself into a new operational domain. Social media, propaganda, social engineering, and information control are expected to be the main drivers of social destabilization, which may be used to promote misinformation, social polarization, distrust, and brain-drain among the population.

In addition, a future **rise in radicalism** is expected to aggravate the risks related to terrorism and organized crime. Certain states could use proxy actors to carry out terrorist and criminal activities to promote unrest and undermine the morale of societies.

While an evolution is expected in terms of tools and methods, hard power demanding high-end capabilities will remain the main driver of warfare..

Social engineering and misinformation

Changes in the military character of war

Terrorism and organized crime

Rise in radicalism

Social media, propaganda, social engineering, and information control are expected to be main drivers of social destabilization, which may be used to promote misinformation, social polarization, distrust, and brain-drain among population.

TECHNOLOGY

Technological superiority is expected to be a major factor in future warfare. The evolution of current technologies and the disruptive nature of new ones will allow significant enhancement of military capabilities but will also pose several challenges for EU armed forces.

Technological advances are already occurring at an ever faster pace. This accelerates the race for technological superiority in many fields such as digitalisation, **biotechnologies and human enhancement**, data management, **space technologies, hypersonic weapons**, artificial intelligence, **new materials**, nanotechnologies, manufacturing processes, and **quantum technologies**.

Increasingly connected and decentralised human networks along with the **persistent digitalisation of society** will bring significant changes to the operational environment. Although the opportunities to access this new digital society are expected to remain unequal, global networks will make instabilities and conflicts more visible to individuals by allowing them to access a wide variety of information about military operations, which may give even more importance to popular opinion.

In the military field, technologies such as human enhancement and new materials will significantly improve the survivability and effectiveness of units and platforms, while the development of novel disruptive weapons (such as hypersonic and directed energy weapons) will bring new opportunities and challenges to the battlefield. Others, like space technologies, artificial intelligence, nanomaterials, additive manufacturing, and quantum technologies will allow to change the way several military tasks are carried out, including command and control, communications, intelligence and surveillance, engagement, logistics or protection of forces.

Accessibility and democratisation of technology are expected to significantly reduce the technology gap between states and non-state actors, leading military forces and state actors to lose their exclusivity of access to high-end technology and weapons. Non-state actors and even individuals will have greater access to advanced armament and technology, which will open new possibilities for hybrid warfare tactics and increase the risks of confrontations, even long lasting in the grey zone.

Space technologies and hypersonic weapons

New materials

Biotechnologies and human enhancement

Quantum technologies

Technology becomes specially relevance in the Grey Zone, driving activities like political and election meddling, cyber threats and attacks, economic coercion, use of proxies, and many other measures – including military action.

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LONG-TERM CAPABILITY TRENDS

The next paragraphs depict the main long-term capability trends identified, describing the associated challenges and the technological leaps. Identification of these capability trends have been driven by the analysis among experts and the need of keeping future military advantage. It is remarkable to note that for these trends to materialize it will be necessary to agree on relevant standardization policies across armed forces and nations.

Fight for Cognitive Superiority.

Multi-Domain Connectivity "by Design"

Pervasiveness of Multilayer Manoeuvrable Engagement

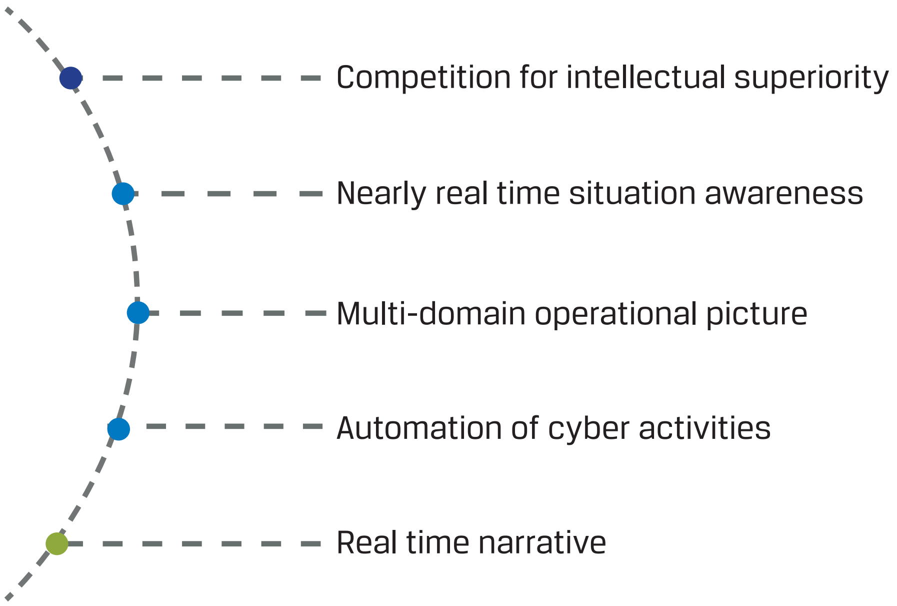
Electromagnetic Spectrum Dominance

Heterogeneous Energy Availability for Operational Environments

Extensive Space Capabilities: from Enabling to Shaping the Future Battlefield

Coexistence of Analogue and Digital Defence Mindsets

FIGHT FOR COGNITIVE SUPERIORITY


Competition for intellectual superiority
Nearly real time situation awareness
Multi-domain operational picture
Automation of cyber activities
Real time narrative

The extensive use of digital technology and the increasing uncertainty in many fields of society have intensified the **competition for cognitive superiority** and the conflict over the perception of reality. It will become increasingly important to learn more quickly and constantly improve cognitive abilities to gain a significant military advantage.

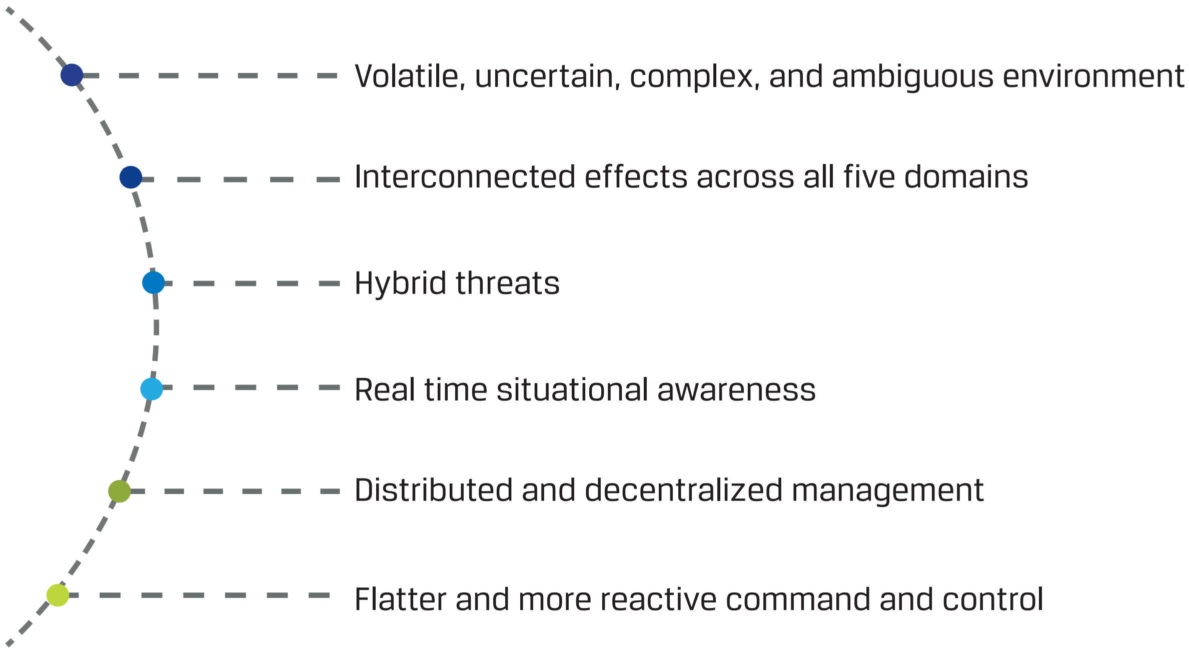
The expected challenge for future technology developments is to reach a **nearly real time situation awareness**. The capability to operate in any domain simultaneously is subject to maintaining a robust cognitive ability and resilience over the adversary, since all actions in traditional domains have effects in the cognitive dimension.

As part of the cognitive superiority, it is expected that by 2040 an enhanced **multi-domain operational picture** will be available to develop a nearly real-time narrative unfolding in a particular crisis scenario, as well as to prevail in the clash of truths.

Technological advance in **big data analysis and artificial intelligence** driven systems will improve the assessment of the Multi-Domain operational environment and determine how to take and keep the initiative in the 'Battle of the Narrative'. In addition, expected developments in **quantum and blockchain technologies** should be considered as enablers to create more robust and **resilient communication systems**.

An enhanced cyberspace situational awareness will be necessary to ensure continuity and early detection of cyber vulnerabilities. The **automation of cyber activities**, backed by various artificial intelligence algorithms, is an emerging and promising trend that holds immense potential in both the present and the future. The great advantage of this automation over human operators is the optimisation, the self-learning ability and the speed to handle complex and data-intensive tasks. **Cyberspace situational awareness** plays a crucial role in identifying the most effective strategy for utilizing communication and information resources, to generate confusion into the adversary and to minimize the effects of hostile disinformation campaigns.

MULTI-DOMAIN CONNECTIVITY "BY DESIGN"



Volatile, uncertain, complex, and ambiguous environment

Interconnected effects across all five domains

Hybrid threats

Real time situational awareness

Distributed and decentralized management

Flatter and more reactive command and control

Nowadays, but also further in the future, the **operational environment is volatile, uncertain, complex, and ambiguous**. These characteristics are accentuated by new technologies and the phenomena of **globalisation, digitalisation, and pervasive connectivity**. This defines a competitive environment that goes beyond the traditional domains of land, sea and air and extends to new domains such as **space and cyberspace**, towards actions carried out across all dimensions (physical, cognitive and information).

This will also imply the ability to employ forces of different sizes and capabilities, from large scale manoeuvres to special operations involving small forces, possibly unmanned. Traditional battlefield evolves into a combat situation based on persistent and multi-domain threats, enhanced by hybrid warfare techniques and new high-tech weapons, to produce **interconnected effects across all five domains**.

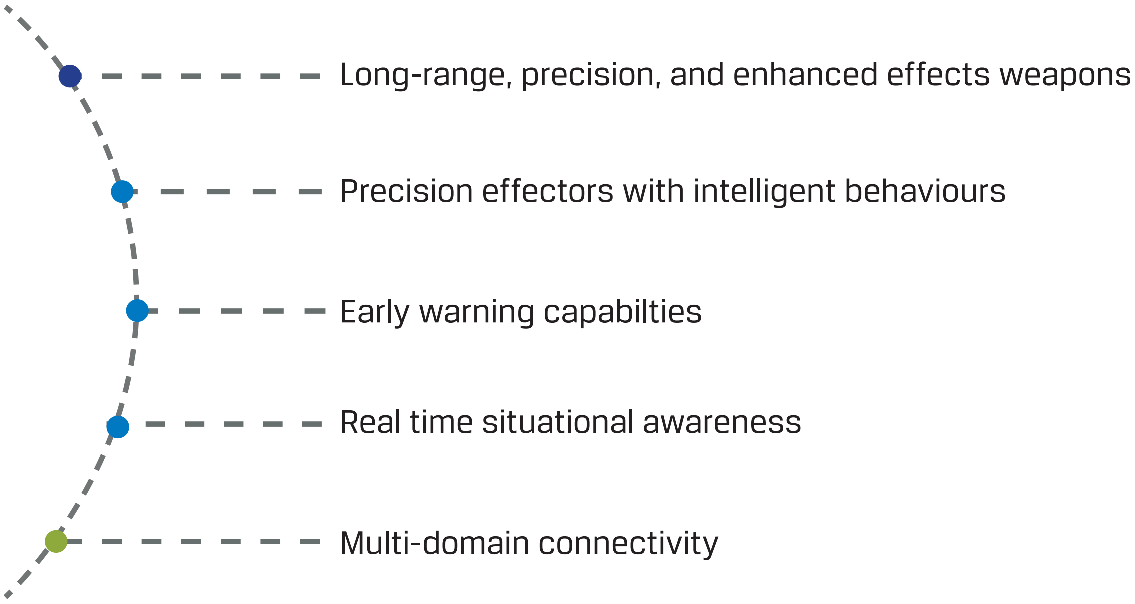
Another relevant element is the possible disuse of the physical frontline concept, in favour of a new type of conflict where actions, including hybrid, take place simultaneously in different spots of the operational theatre, including **non-physical domains**. In the future, multi-domain operations are expected to be capable of better facing **hybrid threats** and deterring adversary actions while maintaining initiative and freedom of action.

Technological developments in the fields of digitalization, communication, and sensors, as well as the ability to analyse, understand, and use data to create actionable information, are expected to require an enhanced multi-domain operational picture to keep almost a **real time situational awareness**. Increasing digitalization of the battlefield will also require strategic and operational planning with decentralized and automated command and control systems to support decision-makers. In this sense, full implementation of the concept of **'combat cloud'**, considering multi-domain and interagency security concerns, will facilitate robust, resilient, and distributed command and control.

The use of digital technologies for **distributed and decentralized management**, is currently being implemented in society and will be of standard use in the next decades.

Robust standardization and validation of processes and procedures will provide full integration between different domains as well as with other institutions or entities, both military and civilian. In turn, the inclusion of autonomous systems, decision support systems or automatic data analysis will make possible to define new organizational structures and a **flatter and more reactive Command and Control** capability allowing better and faster response.

PERVASIVENESS OF MULTILAYER MANOEUVRABLE ENGAGEMENT



Long-range, precision, and enhanced effects weapons

Precision effectors with intelligent behaviours

Early warning capabilties

Real time situational awareness

Multi-domain connectivity

The strong development of **long-range, precision, and enhanced effects weapons** demands integrated air and missile defence systems, including multilayers and robust attrition capacity, to also address the growing swarming threats.

The combination of existing challenges with the application of emerging technologies under development will make it necessary to enhance the integration and the clustering of fully air and missile defence systems. Ballistic missiles, hypersonic weapons and **precision effectors with intelligent and swarming behaviours** represent threats which are difficult to counter by traditional standalone systems. In this sense, aspects such as **early warning** and the integration of advanced sensors, command and control systems and effectors in extended networks become critical for future protection capabilities.

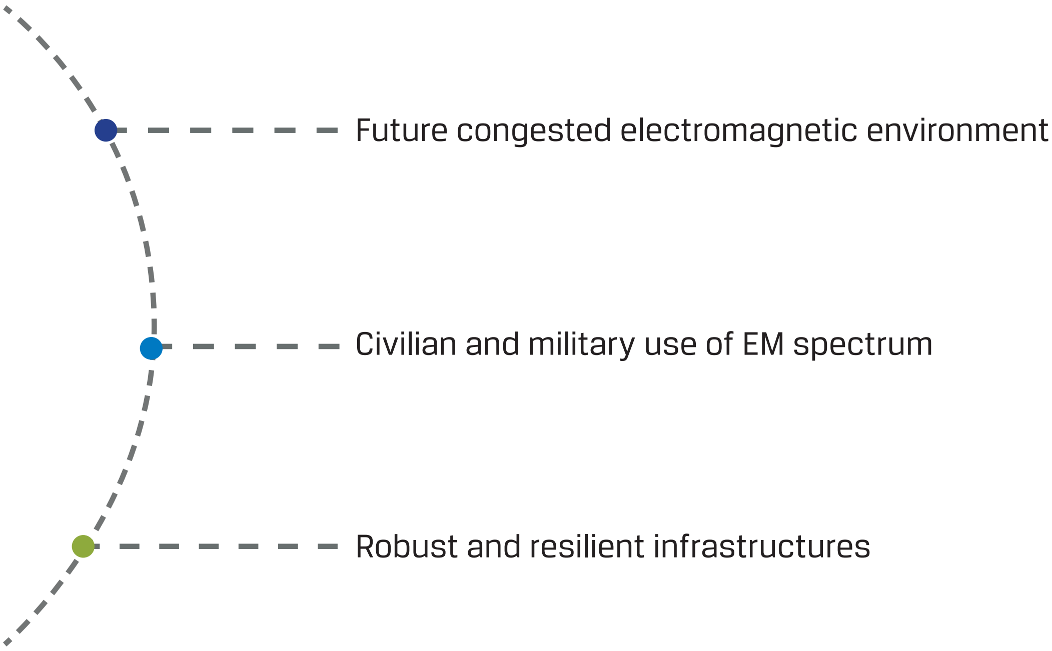
Particularly hypersonic technology is expected to revolutionise the way air and missile defence is conducted. They strongly expand the attributes of air power (speed, range, flexibility, and accuracy) including manoeuvrability capacity which could pose a challenge for detection, tracking and engagement. This implies reduced decision time and limited response options.

An approach based on **multi-domain integrated systems** is considered the most advisable strategy to counter this type of threat. A wide network of sensors and assets, including unmanned aerial vehicles, satellites, and naval and land-based sensors, must act as an integrated data network to detect and react in a timely manner to such threats. The requirements point at the need for a **collaborative, integrated and Multi-Domain protection network**. However, digitalization will also make defence systems more vulnerable to cyber threats and electronic warfare systems.

Another potential threat is the use of **drone swarms**. The increasing availability of drone swarms presents a complex threat to counter, due to their size, number, and mobility. This threat has a high potential to evolve considering the low cost and low resource requirement, meaning that both state and non-state actors can gain easy access to this technology.

The observed general trends exclude a decrease in the likelihood of high-intensity confrontations. In that regard, this trend is of utmost importance to maintain deterrence and the advantage in case of peer-to-peer warfare and, to deliver decisive effects on traditional domains (land, sea, air)

ELECTROMAGNETIC SPECTRUM DOMINANCE



Future congested electromagnetic environment

Civilian and military use of EM spectrum

Robust and resilient infrastructures

Overall connection and digitalization with an increased use of the electromagnetic spectrum by the military forces constitute a perfect target and opportunity for enhanced electronic warfare.

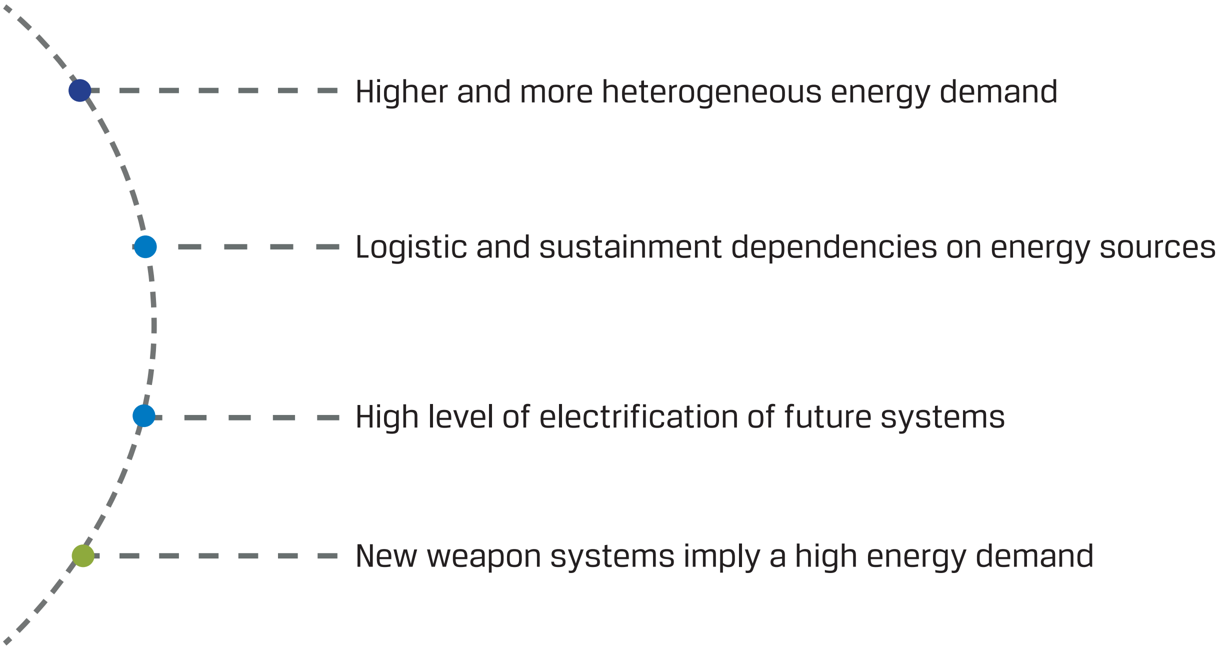
The future **congested electromagnetic (EM) environment** and its related infrastructure will be even more critical due to the huge increase of data management and communications needs. Consequently, electromagnetic spectrum freedom of use will be a substantial part of future warfare including electronic warfare means, cyberspace situational awareness and resilience of networks, both in the physical and information dimensions.

Electromagnetic spectrum operations (EMSO) have a major enabling role for the planning and execution of military operations in all domains, even increasing its importance and complexity, due to a much more extensive digitized and connected world. Thus, electromagnetic spectrum dominance will be a major indicator and a paramount component for achieving superiority in all military domains.

Certainly, the **electromagnetic spectrum** is used **for both civilian and military purposes**, sometimes relying on the same assets and infrastructures, and with a growing demand for use. Consequently, the associated challenges for the unrestricted use of electromagnetic spectrum go far beyond the military component, since they affect the whole economic and social development of modern societies. Therefore, ensuring electromagnetic spectrum freedom of use is crucial for maintaining the daily activities of modern societies based on a digitized and connected world as well as any military operation.

Consequently, technological developments that allow an advantage over the adversary in the electromagnetic spectrum will be essential. They must succeed in evolving **robust and resilient infrastructures** able to confront disruptive electronic warfare threats. This should be especially implemented to protect critical infrastructures (including physical and virtual networks). Cognitive superiority and artificial intelligence technologies may improve operations in the electromagnetic spectrum and help managing the complex and highly congested specific environments.

HETEROGENEOUS ENERGY AVAILABILITY FOR OPERATIONAL ENVIRONMENTS



Higher and more heterogeneous energy demand

Logistic and sustainment dependencies on energy sources

High level of electrification of future systems

New weapon systems imply a high energy demand

Future battlefield, with **higher levels of digitalization, presents a higher and more heterogeneous energy demand**. It includes the need to generate, store, transport, manage and distribute energy most efficiently. This will be particularly relevant due to the proliferation of unmanned autonomous systems, coupled with increasing battlefield sensing, directed energy weapons, and the trend toward platform electrification and other alternative propulsion systems.

This **high level of electrification** will have an impact on generation, but also on **logistics and transportation** associated with storage systems. In turn, **new weapon systems imply a high energy demand** at very specific and unforeseeable moments. In the same way, bases and infrastructures in operational environments will need to be more efficient and self-sustainable, also considering climate change environmental disruption and possible widespread shortage of resources.

Besides efficient and sustainability, other critical requirements refer to ensure energy and power availability and reliability. Power and energy developments, including the overall trend to leverage renewable sources of energy, should cope with future increasing battlefield power demand anytime and anywhere.

As operational energy requirements will be higher and heterogeneous, a comprehensive battlefield energy efficiency, robustness, security, and readiness approach should be implemented. Several technologies will support energy generation solutions (for instance new micro modular nuclear reactors and fuel cells), storage (supercapacitors or advanced high-power batteries among others), management and distribution systems (smart grids and predictive energy management models) will be essential.

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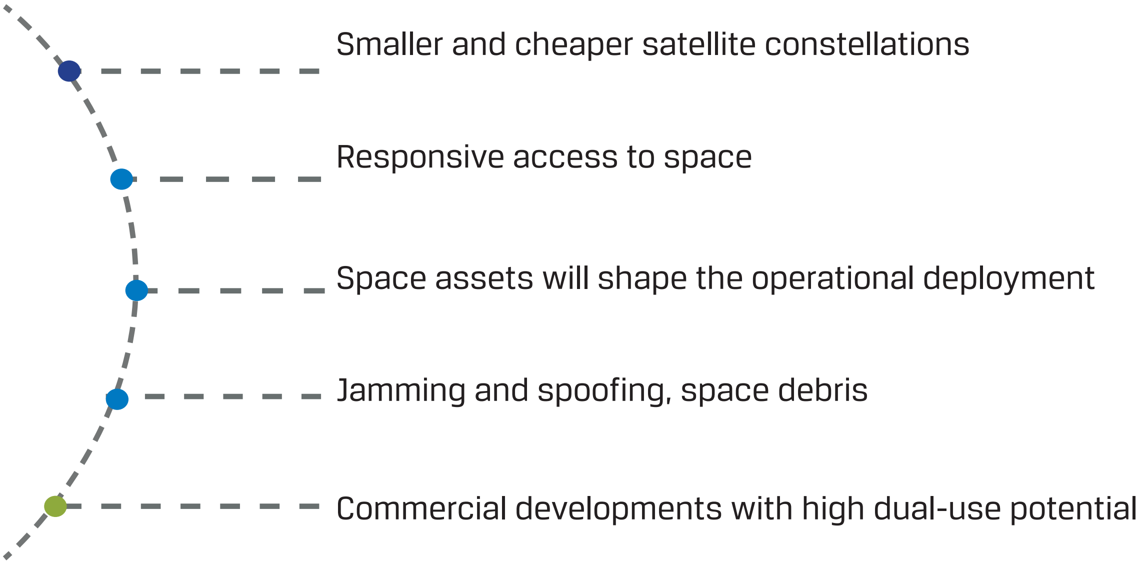
EXTENSIVE SPACE CAPABILITIES: FROM ENABLING TO SHAPING THE FUTURE BATTLEFIELD



Smaller and cheaper satellite constellations

Responsive access to space

Space assets will shape the operational deployment

Jamming and spoofing, space debris

Commercial developments with high dual-use potential

The reliance on space capabilities will significantly rise as the nature of warfare continues to change. The development of **smaller, cheaper, and easier to deploy satellites** will make space an increasingly accessible and contested domain.

Space assets are foreseen to **shape the operational deployment** of many capabilities in all traditional domains, such as improved beyond line-of-sight communications, permanent and real-time surveillance, support for precision weapons as well as for sources of fire detection, intelligence and ensuring effective command and control. Future military operations will depend on the expanded use of space capabilities as key enablers for cognitive superiority, intelligence and high bandwidth communication, and to provide direct effects in all other domains.

In consequence, space assets will have to be robust, reliable, resilient, and redundant to keep high operational availability. Developments in the field of automated self-healing systems as well as higher manoeuvrability ability can contribute to making those assets more robust. New launchers to enable the rapid commissioning of assets will be also paramount to ensure a **responsive access to space**. Besides, reducing the cost of these launches will increase the specific technological competition, to achieve and keep the strategic advantages offered by this domain.

Armed forces will need to develop the related doctrine, training, tactics, techniques, and procedures to optimise the deployment of space capabilities and to shape military operations in all other domains. On the other hand, since space domain will be a field for strategic confrontation, adversary space capabilities constitute a threat, and protective measures will need to be developed. Each asset will be **vulnerable to intentional interference and disruption** like jamming and spoofing, space debris, intentional kinetic attacks, and a wider range of technological threats. Protection requirements will not be limited to providing better orbiting and manoeuvre capacities but include passive measures to mitigate the exposure to disrupting or harming the asset performances.

Another relevant aspect is that the space sector today is significantly impacted by commercial entities. A number of companies and organisations are expected to develop several space **technologies with high dual-use potential** to provide commercial services. Armed forces should adapt their acquisition and services provision processes to maximise collaboration where applicable, keep the technological advantage and secure critical information.

COEXISTENCE OF ANALOGUE AND DIGITAL DEFENCE MINDSETS

World largely digitized and technology dependent
Human evolution from an 'analogue' to a 'digital' mind-set
Dependence on networks and information systems
'Cognitive' supervision of a complex set of devices
Swarms of autonomous platforms
Build trust in automation

By 2040 and beyond, it is expected that the **world** will be largely **digitized and technology dependent**. This will result in a shift between generations' mindsets, with a greater number of people having been raised and educated in a digital environment. This shift will affect the armed forces, with a transition period required to accommodate the different basic abilities. Likewise, legacy military equipment is designed and developed over a long period with co-existing analogue and digital approaches.

Exploiting all the advantages entailed by technological development requires a gradual **evolution from an 'analogue' to a 'digital' mindset**, as well as the adequate coexistence of both.

The increasing level of connectivity is producing (with an increasing trend) a **strong dependence on networks and information systems**. Vulnerabilities associated with possible dysfunctions or intentional actions in the digital environment have crucial relevance.

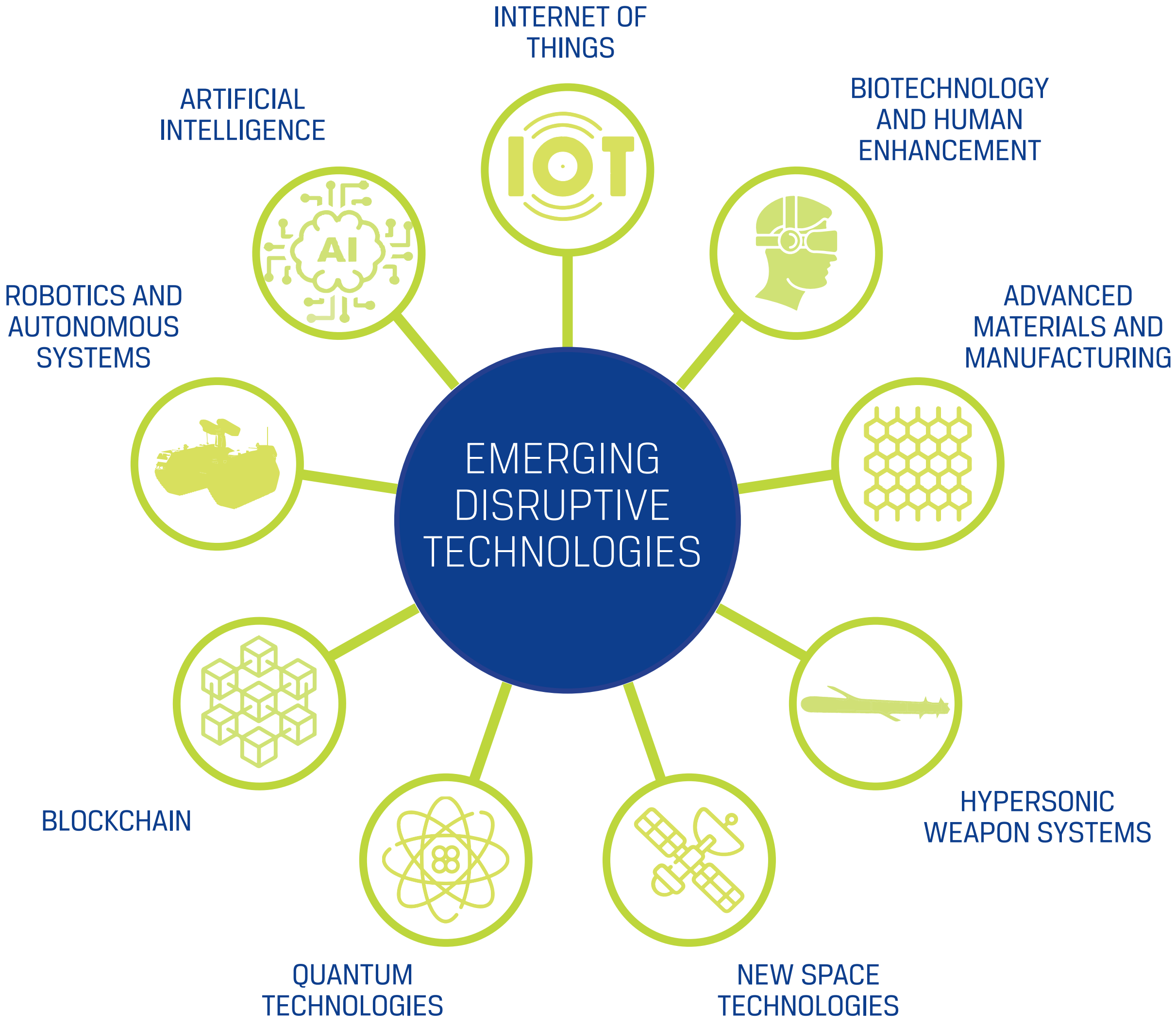
Another critical aspect refers to society possible evolution, coming from future advances in biotechnology, nanotechnology, machine learning algorithms, and advanced materials, as well as from the significant changes in the younger generations' education and attitude towards the digital and analogue dimensions. These technologies will enable a new generation of cognitively enhanced soldiers, more interconnected and with a better understanding of the battlespace. Developments in miniaturization, advanced communications, augmented reality, artificial intelligence-enabled systems, or human-machine collaboration will evolve the concept of system operation from a 'manual' control towards a '**cognitive' supervision of a complex set of devices, systems, and swarms of autonomous platforms**. Armed forces must be adapted to this changing situation and develop a culture that embraces digital technologies but enables personnel to understand benefits and potential associated risks and hazards..

Regarding autonomous systems, the risk of overwhelming reliance on their use must be considered before developing military capabilities highly dependent on autonomy. Armed forces must develop the appropriate tools which allow them to build **trust in automation**.

Finally, it is essential to maintain operational readiness and capacity in degraded environments. As the global security situation continues to evolve and become more complex, military forces must be prepared to respond to threats in a variety of environments and conditions. To do so, they must be capable of rapidly adapting to all fast-evolving operational environment.

TECHNOLOGY IMPACT ON FUTURE MILITARY CAPABILITIES

This section includes a review of the EDTs and their impact on future military capability requirements considering, as main input, the results derived from the TTXs execution. The following sections are introduced by a short and not extensive description of the EDTs, as the main purpose is to look at them from the capability development perspective, to describe possible military applications and next challenges to be considered as part of the future battlespace.


INTERNET OF THINGS
ARTIFICIAL INTELLIGENCE
BIOTECHNOLOGY AND HUMAN ENHANCEMENT
ROBOTICS AND AUTONOMOUS SYSTEMS
ADVANCED MATERIALS AND MANUFACTURING
EMERGING DISRUPTIVE TECHNOLOGIES
BLOCKCHAIN
HYPERSONIC WEAPON SYSTEMS
QUANTUM TECHNOLOGIES
NEW SPACE TECHNOLOGIES
IOT
AI

INTERNET OF THINGS

The concept of the Internet of things exploits the **deployment of numerous sensors** allowing the real-time information collection and analysis of the environment, as well as the persistent monitoring of systems and platforms. The primary objective of this approach is to enable the remote supervision and management of devices, providing valuable insights into the surrounding environment, which facilitates informed decision-making.

The use of extensive networks of sensors deployed in all domains, devices and platforms will offer a decentralized environment that provides a **common operational view** of the situation and will provide valuable data to support decision-making once analysed.

Combined with others, these technologies will also provide greater **supply chain visibility and improve supply and maintenance** operations. Real-time information about status, position, speed, fuel, and other parameters of equipment, systems, armament, and ammunition will help to improve sustainment and reduce the costs associated with deployment and mobility.

For air defence systems, the use of extensive sensor networks that provide real-time information will help to **detect and counter new airborne threats** such as autonomous systems, swarming threats or hypersonic missiles that have different attack vectors from traditional platforms.

From the soldier's perspective, one of the most significant applications is the use of portable devices in support of **health monitoring and medical treatment**, making use of technologies such as biometric monitoring or augmented reality. This will have a direct impact on the way operations such as combat search and rescue or medical evacuation are conducted.

Internet of things provides support for **military training and education**, monitoring personnel either in operational or remote environments. Together with other technologies, such as big data or augmented reality, it also helps to recreate complex environments based on real data offering more efficient, fast, and realistic training in secure environments.

On the other hand, the main concern regarding internet of things refers to cybersecurity. It makes systems more vulnerable to cyber-attacks, and the need for high-capacity wireless networks will require a better protected use of the electromagnetic spectrum.

Another significant challenge refers to the need for interoperability among the different connected devices. A large number of suppliers, technologies, and protocols demand that interoperability standards must be established to ensure proper implementation and performance

.

MILITARY APPLICATIONS

Common operational view

Improved maintenance

Detect and counter new airborne threats

Health monitoring and treatment

Military training and education

ARTIFICIAL INTELLIGENCE

Artificial intelligence-based systems are valuable tools with multiple applications in the military context. Over time, artificial intelligence is expected to take over some parts of decision-making processes. Appropriate verification and validation measures are critical to ensure the effectiveness of the decisions taken by these algorithms.

Certainly one of the main uses of artificial intelligence is its **applications for autonomous systems**. Some existing systems are already capable of autonomous manoeuvre and decision-making. The eventual application of autonomy to the entire engagement chain has ethical and legal implications which have to be addressed in terms of clear rules of engagement and definition of the human role in the decision-making process (i.e. in the loop versus on the loop). The necessity to maintain an effective response to the use of such autonomous system by adversary will drive the conversation in the future.

Artificial intelligence applications are envisaged in cyberspace due to its ability to analyse data and identify weaknesses, to allow cyber offensive and defensive actions. From a strategic perspective, it can have a significant impact on strategic deterrence, such as the ability to detect and collect information related with strategic weapons, which can change the geopolitical landscape and affect nuclear deterrence postures. Together with other technologies, such as additive manufacturing and the use of digital twins, it will have a significant impact on **military logistics**, improving efficiency in the supply chain and equipment maintenance.

In addition, artificial intelligence will also **improve human cognitive capabilities**, such as translation and native language understanding: it will also play an important role in analysing unstructured information to improve intelligence capabilities, including applications such as managing disinformation campaigns and identifying fake news. It should be noted that a critical challenge is identified in the lack of adequate standards and procedures for proper **verification and validation** of artificial intelligence-based systems. These systems present complexities due to their non-deterministic nature and learning capability, requiring enhanced simulation capacities for validation. The establishment of certification policies is essential to ensure resilience and trust in systems that make use of artificial intelligence.

These systems must complement and not substitute human action which calls for developing operational models that allow for **adequate human-machine cooperation**. Human-machine and machine-to-machine interoperability become critical and demand an effort to define open architectures and develop standards to ensure coherent behaviour between different systems, regardless of manufacturer or user. Given the complexity of the algorithms, as well as the large amount of data used, significant risks related to cyber threats and reliance on data are also identified.

Finally, it must be underlined that a gap in the development of this type of technology might represent a significant threat to security and defence.

MILITARY APPLICATIONS

Autonomous mobility

Strategic deterrence

Military logistics

Improve human cognitive capabilities

Verification and validation

Human-machine teaming

BIOTECHNOLOGY AND HUMAN ENHANCEMENT

One of the key applications of biotechnologies and human enhancement technologies is the ability to **monitor the combatants and their surrounding** in real time. This will enable more accurate diagnosis of their health, mood, and general status as well as help to provide a better situational awareness.

Multiple sensors can be integrated into the soldier's clothing or equipment, to monitor various parameters and automatically recommend actions. Regarding the soldiers monitoring, the use of micro-sensors or augmented reality technologies will help to use real-time information and to better control the mission accomplishment.

The use of unmanned systems requires effective integration of human capabilities with robotics and autonomous systems while non-invasive devices will allow for easy **implementation of human-machine collaboration**. More invasive integration connecting the brain and/or nervous tissue with computers does not seem feasible in the short to medium term. Nevertheless, in the long-term these interfaces will allow increased situational awareness and optimisation of decision-making processes.

Neurostimulation and pharmaceutical technologies could be considered as a way to improve training and instruction, and brain interfaces could be used in the future to stimulate and enhance relevant areas of the human abilities.

These technologies enable **remote advanced medical treatments** that were previously only possible in specific medical facilities. This is possible thanks to technologies such as telemedicine, robotic-assisted surgery, biomaterials, or additive manufacturing.

The use of novel materials and biotechnologies in the military domain presents challenges that must be addressed before their application, including legal and moral implications and the toxicity of nanomaterials.

Finally, in addition to **ethical and legal concerns**, these technologies still present some technical challenges, especially regarding the physical constraints surrounding the engineering of metamaterials with acceptable mechanical, thermal, and environmental properties safe enough for human health

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MILITARY APPLICATIONS

Ethical and legal concerns

Management of soldier tactical situational awareness

Human-machine collaboration

Survivability and health support

Augmented / Virtual Reality enhanced training

ROBOTICS AND AUTONOMOUS SYSTEMS

There are many possible applications of autonomous systems in defence as these systems are being rapidly incorporated into military capabilities. It is expected that this process will accelerate in the coming years.

Their use will be greatly enhanced for **information acquisition, surveillance, and intelligence analysis**, as well as in routine tasks, such as border surveillance with minimal human supervision.

The use of autonomous systems allows for **improved combat capability** as the systems are not conditioned by human physical and psychological limitations. The use of such systems in combat could contribute to reduce the risk of losing combatants.

Another application refers to improving transport capacity by automating the transport of cargo and personnel to optimize operations. A combination of manned and autonomous means for transportation allows for redesigning supply networks and achieving better integration between strategic, operational, and tactical transport, and moving towards the concept of 'on-demand' logistics.

In the future, these systems are expected to play an important role in **logistics**. They will have an impact on system maintenance and repair using automated management and distribution of supplies across domains, as well as on operational medical support. Both, in combat and in-field hospitals, autonomy will enable faster healthcare tasks and reduce the need for specialist doctors to be physically deployed.

Autonomous systems can also be used in **electronic warfare tasks** to protect the military assets by detecting and neutralizing threats in the electromagnetic spectrum and to perform offensive actions such as signal jamming.

The main challenge presented by these systems, beyond the technological development, is determining the appropriate level of autonomy to be provided. This will depend on several factors, including the **adaptation of doctrines** to ensure their safe employment and compliance with applicable laws and regulations.

In particular, the **ethical concerns** concerning the use of robots in the entire engagement chain and autonomous systems in military operations is a critical challenge that requires in-depth analysis and the development of the necessary legislation and regulation

.

MILITARY APPLICATIONS

Combat and weapon systems

Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR)

Joint manoeuvre

Autonomy-enabled defences

Sustainment services

ADVANCED MATERIALS AND MANUFACTURING

Advances in new materials and manufacturing techniques have a major impact on military capabilities, and their application in defence covers a wide range of areas, from new metals and production techniques to synthetic biology, nanotechnology, and stealth designs.

The use of **metamaterial-based communication systems** in future systems will provide advanced communication capabilities that will make better use of the electromagnetic spectrum. In addition, metamaterial-based antennas will increase power output, improve directionality, and extend the frequency range, making them useful in both offensive and defensive electronic warfare.

Metamaterials also enhance the performances of **optical and infrared sensors**, enabling higher fidelity and wide-area coverage for increased detection and identification. In addition, these materials also offer protection from a variety of threats, such as chemical, biological radio and nuclear agents, kinetic impacts, weather conditions, and stealth capabilities for survivability and protection.

On the other hand, in **CBRN defence** field, nanotechnology and self-decontaminating surfaces offer advanced solutions for identification, protection and decontamination against modern chemical, biological radio, and nuclear threats, enabling the detection of dangerous particles with minimal energy consumption, as well as providing additional active protection.

These materials also enable the development of more enduring equipment or clothing for extreme environments, including underwater or for outer space. They also allow for the **modulation of visible, infrared, radar, and acoustic signatures**, enabling the reduction of signatures to allow stealth capabilities.

Highly efficient batteries and energy solutions benefit from new material developments, enabling the extensive use of electric and hybrid platforms in a wide variety of applications, from portable devices, vehicles, command and control, sensors, and weapons systems.

Finally, additive manufacturing could transform logistics and supply chains by enabling **remote production of parts, components, and supplies**, including spare parts for vehicles, weapons, ammunition, and medical supplies.

It is important to assess the level of maturity of the technologies in this field, as many of them are still in the early stages of development and are not expected to be effectively applied in the medium term.

MILITARY APPLICATIONS

Protection and concealment

Sensorization and information systems

Power and energy

Medical services and human enhancement

Improved C4ISR systems

Munitions

Maintenance and supply

HYPERSONIC WEAPON SYSTEMS

Hypersonic weapons are a major challenge due to their different behaviour compared with traditional armament and munitions. The specific advanced and revolutionary performances, in terms of **speed, manoeuvrability and trajectory**, require the development of new detection systems and countermeasures that modify current approaches to air and missile defence concepts and architectures.

The main advantage of this type of weapon is the ability to hit long range targets quickly and accurately while hiding from detection systems, limiting the adversary's ability to react and countering anti-access capabilities. The incorporation of nuclear capabilities by some actors could be a paradigm shift in strategic deterrence and increase the instability of the strategic environment by rethinking current nuclear strategies.

In consequence, the development of more sophisticated and effective defence systems is needed at both the tactical and strategic levels.

Due to the **short response times** to such threats, early warning and detection are considered as the foremost enabler to ensure effectiveness of countermeasures. To enhance detection, it is necessary to establish **extensive sensor networks** able to detect during the launch phase, with the interconnectivity and interoperability of defence systems across multiple domains. Architectures based on space sensors, unmanned systems, radars, as well as algorithms based on artificial intelligence or quantum computing to process information in real time need to be deployed.

Regarding interception, **integrated and layered defence systems** are needed for the interception of hypersonic weapons, and ballistic missile attacks. **Non-kinetic effectors** should also be considered as an effective solution, including electronic warfare systems, directed energy weapons or electromagnetic pulses, especially in saturation attacks.

Moreover, such missile defence systems require extensive geographic coverage in tight response time, therefore the cooperation will be decisive to deploy effective capabilities to counter this challenging threats

.

MILITARY APPLICATIONS

Conventional payloads

Enhanced payloads

NEW SPACE TECHNOLOGIES

Reduced technological gaps and decreased production costs are driving the rapid growth of space services, with increased participation of state, non-state, and commercial actors in this domain. The **commercial space sector** has great potential for growth, offering services traditionally provided by government entities.

Space provides critical services needed during military operations, such as communications, observation, and sensing, which are enhanced by the development of space technologies, leading to a significant improvement in the planning, execution, and assessment of operations.

Space based Communications enhance surveillance, intelligence and C2, and enable multi-domain operations while relying less on ground infrastructure. Observation enhances early warning and target analysis services, enabling real-time and comprehensive threat and damage assessment on the battlefield.

The strong growth in the use of space by multiple actors means that this domain is becoming an environment of confrontation, where the **competition for space dominance, as well as the** access denial to potential adversaries, is an emerging reality.

Space assets equipped for engagement, surface systems able to engage space assets, or even space debris' risks, are current and future threats that require the development of appropriate protection measures. **Manoeuvring capabilities, protection and redundancy** are required to minimise the possible loss of a platform in service.

On the other hand, commercial entities, enhanced by increasing private investments, are leaders in developing new space capabilities. To ensure **autonomy in the use of space services** from a military perspective, regulatory requirements related to rights of use, and coordination of space activities need to be addressed.

MILITARY APPLICATIONS

Communications and Positioning, Navigation, and Timing (PNT)

Space as a conflict domain

ISTAR - Intelligence & counterintelligence

QUANTUM TECHNOLOGIES

Quantum technology exploits the principles of quantum physics in technological applications, and its impact has been observed in a number of fields, such as computing, sensors, and communications, improving data collection, processing, encryption, and transmission.

Quantum technologies may be employed for **defensive and offensive operations in cyberspace**, enabling new attack vectors and increasing the effectiveness of traditional hacking methods.

The transmission of information and the security of communications will benefit from quantum technologies, which will enable **secure connection and interoperability** between military systems and devices on the battlefield, such as drones, aircraft, ships, soldiers, and command and control systems.

Concerning command and control, the combination of artificial intelligence and quantum technologies will offer **advanced decision support tools**, enabling the development of more effective and distributed command and control capabilities, to allow a more responsive assessment of the fast-changing operational environment.

They will also improve surveillance, reconnaissance, and multi-domain intelligence by providing **higher accuracy, sensitivity, and data processing** capabilities. In the underwater environment, these technologies will enable better target detection and effective sub-surface communications.

The maturity of these technologies can vary depending on the specific applications in different domains and specific implementation challenges related to resilience and robustness of systems. One of the main challenges is to implement them gradually without revolutionary requirements changes, thus avoiding unfulfilled expectations and mitigate the associated risks.

A major challenge to consider is the impact of quantum encryption on legacy systems with outdated cybersecurity protection. These legacy systems may not be compatible and require significant upgrades. Furthermore, these weak points of the military networks could hamper their use and compromise the overall security of the operations.

MILITARY APPLICATIONS

Cybersecurity

Improved PNT Capabilities

Electronic warfare

Human augmentation, medical devices and bio-sensoring

Quantum underwater warfare

Fast and secure communications

Force protection

Increased situational awareness

BLOCKCHAIN

Blockchain allows information to be recorded in a distributed and secure way, creating immutable digital records applicable in transactions, communications, and supply chains, to ensure privacy and data integrity.

The use of this technology for Command and Control ensures the **authenticity of information** and the proper transmission of orders, leading to more accurate, agile, and automated execution.

Regarding cyber defence, it provides an **additional layer of security**, enabling authentication and validation of data in real time and making it difficult to manipulate or detect by potential adversaries.

It also improves the **efficiency and security of logistics and supply chains** by enabling visibility of the entire supplier network, guaranteeing the origin of parts, and facilitating traceability. It also enables the identification of the entities involved in the whole maintenance process, as well as the certification of parts and components.

On the other hand, the implementation of blockchain-related technologies faces different challenges, including **scalability, energy consumption and regulation update**.

Regarding scalability, it should be noted that blockchain has certain limitations in terms of computing and storage requirements. This is certainly a technological challenge that will need to be addressed, since it will be crucial for the uptake of these technologies into effective military capabilities.

Energy consumption is also a current factor to be considered and it is necessary to work on the development of more sustainable and energy-efficient blockchain solutions.

Within the defence sector, it is necessary to adapt the appropriate **policies for implementation and use** of blockchain, as well as assess the impact it has on doctrine and procedures.

MILITARY APPLICATIONS

Robust and enduring C2 and intelligence

More secure and reliable supply chain

REQUIREMENTS FOR FUTURE MILITARY CAPABILITY AREAS

COMMAND CAPABILITIES

Command capabilities are mainly influenced by those technologies related to **information management and communications**. Thus, technologies such as Internet of things, machine learning or blockchain will be critical for this capability area where cyber capabilities will be used both for defensive and offensive purposes.

Future communications will enable proper interagency coordination, where an integrated network will be crucial to facing misinformation campaigns. Big data and data processing will contribute to assessing the information and framing a robust combined and cooperative combat cloud.

Future armed forces will need **cyber resilient networks** that offer dedicated, integrated, and continuous command and control (C2) applications, data services, and communication during Multi-Domain operations.

Command capabilities will require a strategic and operational planning with **automated and decentralized C4I** (Command, Control, Communications, Computers, Intelligence) to support the decision-making process. Future command and control systems should apply a distributed approach, resilience towards electronic warfare and cyber threats, as well as adaptability to fast emerging concepts and doctrines.

The congested environment will be affected in the future by technological developments, especially those in the fields of EDTs such as new space technologies, autonomous systems and robotics, human enhancement, quantum and blockchain. Space domain footprint and redundancy, in particular, will contribute to enhance communications to enable better interagency coordination among stakeholders.

New advanced sensors based on quantum technologies will collect more available data and gain an advantage through situational understanding. Therefore, support from quantum computing and automated data processing will be needed to help strengthen the decision-making process.

Command, control, and communications will need to be supported by **quantum and blockchain technologies** to ensure and enhance communication security. Blockchain applications could improve Big data management and strengthen cyber defence, as well as secure defence supply chains and reinforce the resilience of communications.

INFORM CAPABILITIES

Information and cognitive superiority will be a key aspect in the future operational environment, characterized by an ultra-digitized and connected society with vast amounts of information to be shared. Being capable of collecting, processing, analysing, and transmitting all this data timely and securely will be essential for military intelligence activities. Several technologies will be the drivers of future information capabilities, particularly those related to communications, connectivity, big data management and analysis, and digitization.

In the future battle for information, **space and cyberspace** domains are expected to be the **main providers of situational awareness** for armed forces. Cyberspace will be the main channel for storing and transmitting data managed by military forces, as well as the host for all the information shared by society on digital media, which will become increasingly important for cognitive warfare. On the other hand, space will be an increasingly contested domain due to the use of satellites and other space assets to conduct surveillance, provide communications, and collect intelligence. In this field, cooperation with civilian and private sectors will be paramount since they are expected to play a crucial role for the technological development in this specific domain.

Other technological developments will also bring new opportunities for intelligence gathering, transmissions, and data analysis, such as unmanned and autonomous systems, advanced sensors, internet of things devices, artificial intelligence, and blockchain. Developments in sensing technologies will allow the collection of higher-quality data by using miniaturized, low-cost, and quantum sensors. Data security will benefit from blockchain technology and quantum cryptography to secure data storage and transmissions, while internet of things applications will create extensive information networks across all domains to improve situational awareness and provide common operational pictures to the commanders on the battlefields.

Artificial intelligence will be the **key enabler** of future **data fusion and analysis** systems, which are expected to be capable of rapidly analysing vast amounts of data, extracting valuable information, and disseminating it without human interaction. Likewise, AI enabled systems will have a significant role in information control and counterintelligence activities, which will also be increasingly important to maintain cognitive superiority over adversaries.

The importance of the battle of narrative must also be mentioned, since the information from military operations and conflicts are expected to become increasingly available to the public. **Cyberspace** is expected to be exploited for future **misinformation** campaigns and **propaganda**, aimed to alter public opinion and possibly contribute to destabilize societies. Military forces will need to leverage social media and other relevant media channels to conduct information and psychological operations, as well as to protect population from adversary's influence and misinformation campaigns.

ENGAGE CAPABILITIES

Engagement capabilities will be improved thanks to the development of a **new generation of weapons and platforms** that will produce great changes in the confrontations. Likewise, the use of hybrid warfare tactics, information warfare, and psychological operations will play an increasingly important role on the battlefield.

The implementation of technologies such as new materials, better sensors, and artificial intelligence, among others, will allow the development of **smart munitions** with greater precision, power, and range. It is expected that the use of this weaponry will allow for faster engagement, at greater distances, and with less risk of collateral damage.

Improvements in energy production and storage will enable the development of **directed energy weapons (DEW)** with increased range and power, allowing their use for a wider range of purposes across all domains. These weapons, both lethal and non-lethal, are expected to be a powerful means of countering several emerging threats, such as drone swarms or hypersonic missiles.

Electronic warfare and cyber offensive means will play a major role in controlling the heavily congested electromagnetic spectrum of future battlefields, which will be critical to achieve military superiority. The development of enhanced and inexpensive sensors will significantly improve electronic warfare systems, which will be a powerful effector against critical infrastructures, communication networks, platforms, and other critical assets. Likewise, **cyber-attacks** will be used to disrupt or degrade adversaries' assets remotely and even anonymously, which will bring several possibilities and challenges for military forces.

Robotics and autonomous systems will be broadly integrated into military units, performing a great variety of functions in several missions. Autonomous platforms, manned-unmanned teaming, and the related adaptation of tactics will bring several challenges to force protection but will also present new opportunities to carry out missions with less risk to human life.

Human enhancement could also be a disruptive factor for engagement capabilities. Technological developments in the fields of exoskeletons, wearable sensors, brain-computer interfaces, AI-driven systems, augmented and virtual reality devices (AR/VR), and synthetic biology devices will enable significant improvements to soldiers' physical and cognitive abilities.

PROTECT CAPABILITIES

Future operational environment challenges and threats will call for major improvements in force protection for personnel, vehicles, infrastructures, facilities, and all military assets.

The use of **novel materials** will enhance physical protections, such as vehicles' armour, personal equipment, and infrastructures, among others. Advanced materials will also enable the development of new medical equipment, such as synthetic biology devices, and better protection tools against CBRNE agents. The **effects of climate change** must also be considered for physical protection. Equipment, materiel, platforms, facilities, infrastructures, personnel, and particularly electronic systems will need to be capable of operating in evermore extreme and fast changing environmental conditions.

Since the cyber domain is expected to be the place where a vast amounts of critical information for military operations will travel, **cybersecurity** will be one of the pillars for future force protection. Leveraging new technologies, such as quantum cryptography, AI enabled or driven systems, and internet of things (IoT), will be necessary to protect digitized assets and information networks from cyber-attacks. **Cryptography** and active cyber countermeasures will also be key to protecting communications and avoiding unwanted interception of data transmissions.

The extensive use of **robotics and unmanned systems** is expected to be an essential part of future force protection, since their use in all kinds of missions will reduce the risk to human lives. However, these automated and digitized assets also entail the challenge of their vulnerability to cyber-attacks, electronic warfare, and directed energy weapons. Also, enhanced use of autonomous systems entails the threat of swarm tactics, which will call for enhanced defensive measures capable of dealing with significant numbers of autonomous assets.

Artificial intelligence enabled systems will be capable of automatically generating responses and exposing adversaries' deceptive behaviours and influence, including through social engagements, news reactions, messages, publications, reports to decision-makers, warnings, etc. Likewise, artificial intelligence will allow the coordination of detection systems, automated weapons and active protection systems to engage potential threats without human intervention and provide better protection to platforms, facilities or lines of communications. Different degrees of automation for security measures will also improve anti-access/area-denial capabilities with the use of new effectors, weapons, and non-kinetic means, including directed energy weapons, electronic warfare, cyber means, and increased range artillery.

Advanced sensing means, such as quantum sensors, space assets, extensive detection networks, and miniaturized sensors, will detect possible threats with increased precision and at larger distances. These improvements will be essential to detect and engage advanced stealth platforms, small assets, and fast-moving threats in all domains.

DEPLOY CAPABILITIES

It is expected that future deployment activities will be highly impacted by developments in the field of artificial intelligence, robotics and autonomous systems, human enhancement, as well as the overall digitized and interconnected world.

Readiness and rapid deployment capabilities will be necessary to ensure the capacity to react and confront fast shifting conflicts in an operational environment with increased tempo. Individuals, equipment, infrastructures, logistics lines, and platforms must be prepared for rapid commanding, mobilizing, and deployment, to ensure they are fully operational upon arrival at the theatre. This will call for more resilient, flexible, and affordable platforms, infrastructures, and installations.

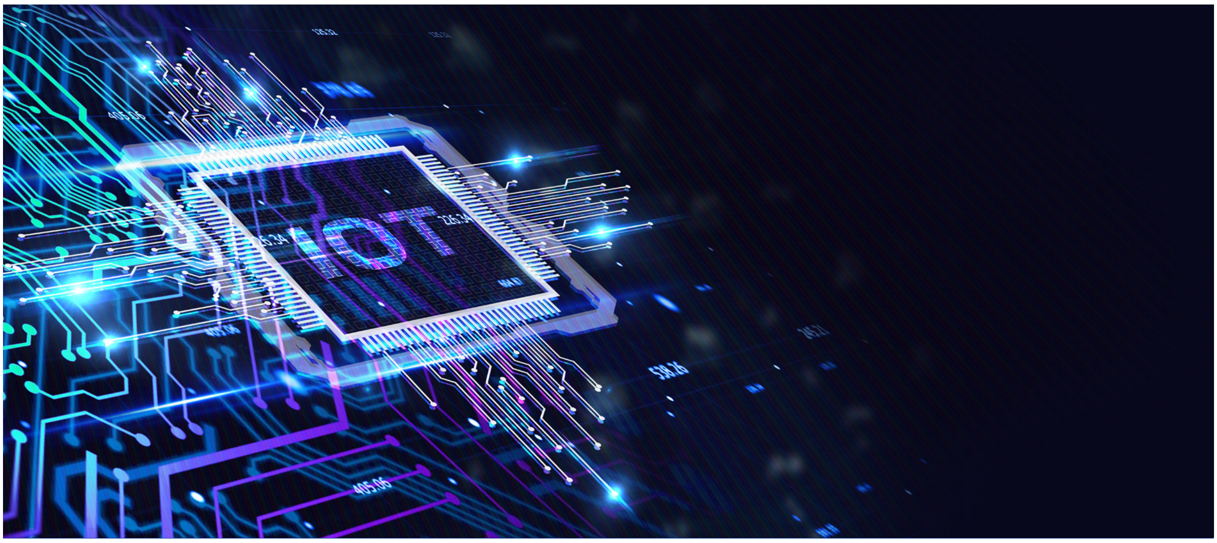
The exploitation of hybrid warfare and grey-zone tactics will make **surveillance capabilities** evermore important in detecting and excluding hostile presence from the theatre. Using autonomous systems, space assets, and surveillance networks, along with civilian and commercial infrastructures, will be critical to conduct persistent control of adversary movements and identifying possible threats. Interaction with civilian entities will also reduce the number of military facilities dedicated to deployment and ensure the ability to exploit host nation aerial, maritime, and land transport infrastructures, as well as hubs and reception-staging infrastructures.

In addition, using modular and scalable m**ulti-role platforms** will be necessary to maximize the tasks of all vehicles and minimize dependence on specific-purpose units. It will reduce the dependence on special purposes platforms, improving opportunities for collaboration, and decreasing the related logistic footprint.

In order to improve **freedom of movement** and safety, most assets, and platforms (ground, maritime and aerial) will need to have sufficient defensive and concealment capabilities to ensure their security and minimize their dependence on external security resources. This will call for units suited with detection systems, active and passive protection systems, and more firepower.

Using innovative materials, such as nanomaterials and self-healing materials, will allow the development of platforms with reduced weight and improved mobility. Besides, using alternative fuels, such as biofuels or even exploiting electric and hybrid propulsion, could also improve the efficiency of those platforms.

SUSTAIN CAPABILITIES



The future operational environment will call for major improvements and changes in military sustainment capabilities. Future tactics and technology developments will change many aspects of sustainment tasks, though they will also bring several challenges to logistics and supply chains. Several technologies, such as robotics and unmanned systems, internet of things, and artificial intelligence, among others, will have major impacts on how sustainment tasks are planned and conducted.

The wider use of **robotics and autonomous systems** in logistics will allow to improve overall efficiency while reducing sustainment risks and personnel needs. These systems could carry out several logistic tasks, including medical treatment, transport of supplies, maintenance, equipment recovery, and support in humanitarian missions and disasters, among others. Particularly, using robotics for medical tasks could improve combatants' survivability by providing the ability to treat personnel remotely and assist them in shorter response time.

Improving the efficiency and traceability of sustainment tasks will require **cloud-based data networks** supported by artificial intelligence models, to provide real-time information to decision-makers, as well as to monitor and plan units' requirements and services. Using these data networks, the logistic systems could take advantage of artificial intelligence enabled systems to manage stocks, plan certain services, and predict specific needs, such as spare parts, medical supplies, personnel services, etc. Monitoring the status and needs of all platforms, units, facilities, and stocks will also require advanced connectivity and high-bandwidth communications capable of providing real-time information to sustainment decision-makers (internet of the things).

In addition, virtual representation technologies such as **digital twins and augmented reality** devices could be useful tools to improve sustainment services as well, including maintenance tasks, personnel services or telemedicine. Likewise, 3D printing, and **Additive Manufacturing** are expected to be a powerful enabler to reduce logistics footprint with the ability to produce specific components locally, including synthetic biology devices for medical tasks. It will have a significant impact on mobility, therefore on the survivability of the ground-based assets.

Another factor to be considered is the impact of **climate change** on the operational environment, such as natural disasters and fast-changing extreme weather conditions. Supply chains will need to be adapted to the demands that these conditions will bring, such as maintenance services and readiness to perform also an increasing amount of possible humanitarian missions and civilian evacuations.

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