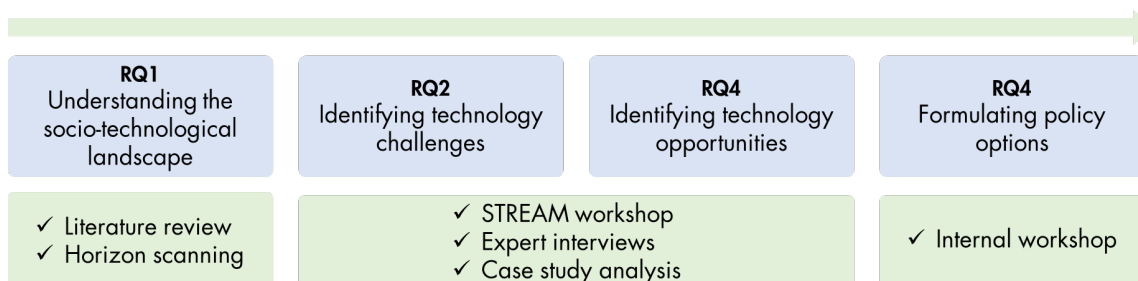


# Innovative technologies shaping the 2040 battlefield

Looking ahead towards 2040, the global innovation and technology landscape is expected to evolve significantly and drive changes in the nature of warfare and the capabilities used by actors on the battlefield. Understanding how the technological landscape will evolve and what impact this will have on the future battlefield is key to formulating policies and investment decisions that are, as much as possible, future-proof. In this context, the study on which this options brief draws examines the challenges and opportunities arising from the new and emerging technologies expected to shape the 2040 battlefield. The figure below provides an overview of the research questions (RQs) that guided the study and the methods and approaches employed to address them.

Overview of study RQs and research approach



## Technological change and the 2040 battlefield

The future battlefield will be shaped by the interaction of technology with various political, social, economic, environmental and technological strategic trends. In particular, the study investigated the implications of possible advances in: **(1) artificial intelligence, machine learning and big data; (2) advanced robotics and autonomous systems; (3) biotechnology; (4) technologies for the delivery of novel effect; (5) satellites and space-based technologies and assets; and (6) human-machine interfaces.** The study identified several cross-cutting implications of new and emerging technologies for future battlefield dynamics and European defence.

Technological change alone is unlikely to fundamentally alter the nature of the future battlefield but will continue to shape the character of warfare

Technological change itself is unlikely to result in fundamental shifts in future battlefield dynamics. Rather, it is the adaptation of military establishments and armed forces (including shifts in strategic mindsets and organisational culture), as well as wider socioeconomic and cultural factors that are likely to shape future trends in the uptake and adoption of new and emerging technologies on the future battlefield. Technological change, while pervasive, is not expected to diminish the importance of human factors or significantly reduce the uncertain or unpredictable nature of war. Emerging technologies, however, are expected to continue to shape both conventional and unconventional warfare. This will require an equal focus on the impact of technologies on above- and sub-threshold activities, potentially blurring the boundaries between the two.

## The full effect of technological advances may only materialise in conjunction with enabling infrastructure or other technologies

Technological advances can have an enabling or constraining effect on advances in other technological areas. As such, interactions among technological trends need to be considered to fully understand the future impacts of technological change. Furthermore, the extent and manner in which new and emerging technologies will be used by EU Member State armed forces will also be shaped by the ways these and other technologies are adopted by adversaries. Access to and control of data will represent a key cross-cutting enabler on the future battlefield, with new and emerging technologies also providing new opportunities for collecting, managing and analysing data to achieve superiority on the battlefield. While future technologies will exacerbate the complexity of future battlefield interactions, they will also offer new avenues for navigating that complexity.

## Technology adoption, shaped by EU-specific enablers and barriers, presents opportunities for EU Member State armed forces, but may also create new vulnerabilities

Technological advances may be seen as heralding qualitative improvements to future forces. They also, however, raise considerations regarding the resilience and ability of forces to rebuild from a quantitative perspective in the event of a loss of technological superiority. Similarly, increased reliance on technological solutions may increase the risk of systemic disruption caused by single points of failure or vulnerability that may need to be managed by means of non-technological approaches to fostering resilience.

The ability of the EU and its Member States to navigate an increasingly complex technology and innovation landscape effectively represents a key enabler to achieve superiority on the battlefield. To foster and retain this, continued efforts are required to attract technological expertise, foster innovation, and establish relevant policy and regulatory mechanisms to guide investments in technological research and development. Divergences among EU Member States, however, may exist with regard to access to new and emerging technologies, financial and cost-related barriers and differing strategic mindsets. As such, national enablers and barriers may also shape individual adoption pathways for new and emerging technologies among the EU Member States.

## Policy options

Looking towards 2040, technological and broader political, social, economic and environmental trends may result in a future marked by uncertainty, complexity and rapid change. This study presents three sets of policy options for EU and Member State institutions to consider in their ongoing effort to prepare for and shape this rapidly evolving landscape. The policy options focus on capability development initiatives, the regulatory and organisational environment, and EU investment in research, development, technology and innovation (RDT&I).



### Pursue a broad range of capability development initiatives

Future technological developments may render existing capabilities obsolete and generate requirements in terms of fostering and sustaining new skills, systems and approaches. Future technological developments may also result in a broader spectrum of sub-threshold activities. These will require initiatives to ensure cohesion of the EU and of Member State societies and institutions, as well as those of its broader alliances and partnerships. Within this context, EU and Member State institutions should continue to pursue a broad range of capability development investments, guided by the following principles:

- 1 **continue to monitor science and technology developments to assess corresponding opportunities and threats.** Efforts should be made to conduct rolling horizon scanning and threat assessment activities to take stock of new and emerging technology developments and their associated implications, opportunities and threats;

- 2 **identify priority areas for capability development to be pursued through joint initiatives to facilitate EU cooperation and interoperability.** Care to ensure interoperability in key areas of capability development (e.g. command and control), avoiding duplication of efforts and enhancing readiness, should be balanced with fully exploitation of national expertise and specialist skills. Existing structures and policy initiatives, including permanent structured cooperation (PESCO), the European Defence Fund (EDF) and the European defence industrial development programme (EDIDP), should be considered for capability development initiatives resulting in interoperable-by-default outputs;
- 3 **identify continued areas for strengthening cooperation and coordination with NATO and key non-EU allies.** EU and Member State institutions should strengthen cooperation at working level and in the context of individual initiatives with NATO and other non-EU allies.

## Foster regulatory and organisational agility and absorption capacity

The evolving technology landscape suggests a need for EU institutions and Member State defence establishments to create an environment that is conducive to the effective and efficient harnessing of positive impacts of technological advances and to the mitigation of any vulnerabilities. As such, EU Member State armed forces and their broader institutional and organisational frameworks should work to foster the capacity and agility required to respond to technological advances and to:

- 4 **contribute to the development and uptake of norms, regulations and appropriate legislation for new and emerging technologies,** including for those technologies emerging from outside the EU. EU and Member State institutions should explore options for shaping relevant legal and regulatory standards for the use of different new and emerging technologies both within the EU and globally;
- 5 **ensure the fostering and retention of an adequate skills base.** There is a need for initiatives to foster and retain a broad range of skills for harnessing technological advances both within EU Member State Armed Forces and the broader defence industry. This should include the development of common training approaches and resources as well as fostering strategic dialogue between EU and Member State institutions, industry and actors in the training and education sector;
- 6 **consider the impact that new and emerging technologies will have on concepts of operations and interoperability.** EU institutions and Member States should pursue initiatives to experiment with, design and iteratively develop tactics and concepts of operations in light of technological advancements and wider strategic developments. This can include gaming, modelling and experimentation.

## Facilitate EU investments and RDT&I activities in relevant technologies by strengthening collaboration with industry

RDT&I in many new and emerging technologies are driven by private sector actors, often originating outside the traditional defence industrial base. This presents increasing challenges to EU Member States and their establishments to harness and adapt to technological advances – especially as these advances occur at a fast pace, are globally accessible, and fall outside their direct or exclusive control. The following policy options are identified in the study for addressing these challenges:

- 7 **identify means for providing industry with clear guidance on future military requirements in order to help incentivise and guide investment.** EU institutions and Member States should strengthen foresight and mechanisms to facilitate access for industry to clear guidance on future military requirements. This should incentivise and guide investment in relevant RDT&I activities with industry, including through non-traditional structures for innovation;
- 8 **explore ways to broaden and sustain engagement with companies developing dual-use technologies.** Given the dual-use nature of many new and emerging technologies, EU institutions and Member States should work to broaden their engagement and mutual understanding with non-defence private sector actors developing dual-use technologies.

This should include communicating their needs and requirements more effectively to non-traditional defence suppliers, as well as identifying ways of generating incentives for such companies to invest in RDT&I, focusing on possible defence applications.

## Additional principles for consideration

In addition to the individual policy options, a number of principles should be considered by EU and Member State policy- and decision-makers when developing and pursuing initiatives relating to the impact of technological developments on the future battlefield. These include:

**adopting a broad range of initiatives.** A wide array of strategic and policy measures will be required to prepare adequately to foster, absorb and leverage technological innovation. This will mean focusing on a suitable combination of mutually reinforcing policies and initiatives, not limited to procurement but covering all dimensions of capability development (e.g. organisational absorptive capacity and awareness raising and training);

**placing emphasis where possible on technology-agnostic approaches.** Given the high level of uncertainty as to the future direction of technological change, technology-agnostic approaches may offer greater resilience against multiple possible futures. Technology-specific initiatives should be integrated in the context of broader efforts to foster preparedness, resilience and adaptability from a general innovation standpoint. This could include establishing R&D grant schemes focused on specific technologies, and broader initiatives that foster organisational approaches to harnessing and absorbing technological advances;

**prioritising investments according to a clear intervention logic.** Future policies and initiatives should be accompanied by adequate planning, ex ante analyses and adequate monitoring and evaluation activities. This should ensure that initiatives and policies are relevant, coherent, effective, efficient and linked to a clear overarching intervention logic;

**adopting approaches and initiatives that are cognisant and reflective of advances in technological innovation in the context of defence.** EU institutions and Member States should pursue approaches that acknowledge and are able to rise to the many challenges stemming from the pace and breadth of technological change. This includes nuancing traditional concepts of technological superiority and possibly adapting procurement cycles. Such changes would for instance allow for early fielding and iterative capability development.

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