# Defence Technology and Innovation Strategy (ETID) - 2020

**STATE SECRETARIAT OF DEFENCE**

**General Directorate for Armament and Materiel**

MINISTRY OF DEFENCE

# Defence Technology and Innovation Strategy

# ETID – 2020

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**General Directorate for Armament and Materiel**

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# Letter of promulgation from the Secretary of State for Defence

The current global strategic context in which the activities of our Armed Forces are framed is characterised by rapid and profound changes and transformations which, inevitably, make it necessary to constantly update their military capabilities. This demand for new capabilities to respond to these new challenges with the necessary speed and effectiveness involves major technological challenges and is a key reference for guiding the main efforts in defence RDI. It is also precisely the global nature of this technological progress, and especially the increasingly easy access that terrorist and insurgent groups have to it, that has turned it into one of the greatest threats to global security.

The development and enhancement of this technology in our favour is, therefore, the best opportunity to increase the performance of the systems and equipment that underpin military capabilities.

Such technological progress must be supported by technological and industrial capabilities that are primarily based in our country and that make it possible, on the one hand, to maintain the freedom of action of our Armed Forces and, on the other, to be a reference in the construction of this industrial fabric that contributes to strengthening the European defence market. In this scenario, the word "cooperation" is the leitmotiv of the times. Cooperation at national level, within the framework of the Law on Science, Technology and Innovation and the Spanish Science, Technology and Innovation System; cooperation at European level, taking advantage of the opportunities that are opening up within the initiatives promoted by the European Union, such as the Horizon Europe framework programme and the European Defence Fund; cooperation with our allies, within the multilateral organisations of which Spain is a member; and cooperation with our partners in the field of bilateral relations. Cooperation, in short, that should not jeopardise the development of our country's technological and industrial capabilities.

These factors, together with the guidelines of the National Defence Directive (DDN 2020) and the objectives and guidelines of the Defence Policy Directive (DPD 2020), are the main reasons behind this new version of the Defence Technology and Innovation Strategy.

This new Strategy, conceived to advance in the basic and primary objective of equipping our Armed Forces with the necessary military capabilities in RDI, providing advanced technological solutions that, in turn, support the strengthening of the technological and industrial capabilities of our scientific, technological and industrial fabric, will also serve to guide the RDI activities promoted throughout the Ministry of Defence, bringing their contribution into line with the achievement of the RDI policy objectives and the specific objectives set out in this document.

To ensure that this Strategy contributes to the achievement of the Military Capability Objective established by the Chief of Defence Staff and helps to achieve the military capabilities required in its Long-Term Force Objective, its implementation has been synchronised with the development phase of the Defence planning cycle.

Our vision focuses on having a defence RDI system capable of taking advantage of both the Department's own capabilities and resources and the external opportunities it can access, acting in all technological areas that are ultimately relevant to the missions of the Armed Forces.

To achieve this vision, the Strategy sets out three guidelines that should be followed by any RDI activity promoted within the Ministry of Defence and which, in turn, constitute the three pillars that will frame its actions.

The first pillar – technological objectives – involves orienting RDI investments towards achieving the technological objectives set out in this Strategy, taken from the RDI lines of interest to defence.

The second pillar – cooperation – provides guidance on promoting actions that lead to increased levels of cooperation in national and international RDI. At national level, the General Action Protocol signed between the Ministry of Defence, the Ministry of Science and Innovation and their funding agencies will play a particularly important role, while at international level, the European Defence Fund and, to a lesser extent, the Horizon Europe framework programme, will be the drivers of cooperation.

The third pillar – continuous improvement – seeks to ensure that the Ministry of Defence becomes a catalyst for RDI and a promoter of the inclusive talent that will bring out the best in each and every stakeholder of the Spanish Science, Technology and Innovation System, so that together we can turn this country into a driver of progress and innovation that leads to a cutting-edge scientific and technological fabric and, therefore, to quality employment and greater well-being in our society.

This Strategy is thus framed, as a sectoral strategy, within the Spanish Science, Technology and Innovation Strategy, and aims to use, through joint actions with the responsible agencies, the instruments of State Plans for Scientific, Technical and Innovation Research (PEICTI) 2021-2023 and 2024-2027, to contribute to achieving the technological objectives established.

Finally, it should be noted that this is a global strategy of the Ministry of Defence and, therefore, the entire Department must follow its guidelines, facilitate its actions and pursue its objectives.

Thus, with the approval of this Defence Technology and Innovation Strategy, the first step has been taken to achieve our shared vision of defence RDI. The task now lies with the General Directorate for Armament and Materiel to draw up the implementation plan and establish the monitoring mechanisms included in this document in order to keep me regularly informed of the progress made in its execution.

Secretary of State for Defence

# Foreword by the General Director of Armament and Materiel

This Defence Technology and Innovation Strategy (ETID 2020) is an update of the Strategy published in 2015, adapted to the current situation and the foreseeable future of the defence sector in the coming years.

Many factors have been taken into account in performing this review. Among them, the emergence of new threats to defence, which obliges the Armed Forces to equip themselves with new military capabilities, or the current accelerated technological progress which, while offering opportunities for the development of more advanced systems, introduces new challenges for the future. Also of importance, in a national context, is the drawing up of a new Spanish Science, Technology and Innovation Strategy for 2021-2027, the general framework in which national RDI, including that of the defence sector, will be developed. This opens up new opportunities for the national technological fabric to strengthen its capability development. And, in an international context, the increased European support for the defence sector of recent years opens up a new landscape of opportunities that must be understood and pursued. Other factors can also be added to the foregoing, with profound implications for national production capabilities, security and global sustainability, including the disruptive changes triggered since the beginning of 2020 by the COVID-19 crisis.

This Strategy has also been developed considering all the actors that, to a greater or lesser extent, participate in the defence sector (Armed Forces, those responsible for managing RDI in the Ministry of Defence, researchers and technology developers, national RDI funding bodies, other collaborating agencies, international organisations linked to defence RDI, among others), and society in general, so that everyone can understand the path to be followed, and so that all parties can see their own contribution to the construction of a future reality that affects us all.

Although the changes I have mentioned so far are profound, what has not changed is the very essence of the mission of the defence RDI policy: to contribute to the development of military capabilities and help shape the national technological and industrial base so that it has the essential defence capabilities it needs. This mission, together with the other elements that make up this policy, namely the vision that explains where we are heading, as well as the values present in all defence RDI activities, is the basis underpinning the entire Strategy. Understanding this and taking it on board helps to understand all the analyses and activities that are developed throughout the document and, therefore, the first chapter describes this policy.

In the second chapter, a detailed analysis is made of the main dimensions and factors that influence the path undertaken by this Strategy. Specifically, an in-depth look is taken at the military capabilities expected to be developed, emphasising the current and future defence contexts and their implications for the characteristics and functionalities of future systems. The nature of technological progress is also stressed, both in terms of the strategic and other changes it introduces and in relation to the multiple ways of managing RDI for our own benefit. And finally, the stakeholders involved in defence RDI are examined, namely the technological and industrial base, other agencies responsible for organising or funding national RDI, international organisations linked to defence RDI, as well as the Department itself, which plays a central role, acting as director and coordinator of RDI, as end user of the systems and funder of part of the RDI activities.

In the third chapter, once the basis has been established and the influencing factors understood, the Strategy is portrayed, built on three interconnected pillars. The first pillar concentrates on the Department's RDI investments in technological objectives that have a high impact on the improvement of current and future military capabilities. The second pillar reinforces technological cooperation activities at national and international level, thereby enabling RDI advances, including dual ones, to be leveraged, achieving multiplier effects, as well as tackling high-cost and complex technological challenges. And the third pillar seeks excellence in the Department through the continuous improvement of its processes, adapting them to change, so that they can act as catalysts for technological progress in the Armed Forces and the technological development of the defence sector.

These pillars, which define the actions to be carried out during the Strategy's period of validity, aim to provide defence RDI with greater robustness and continuity in the face of changes and variations in the economic situation, to achieve a greater dimension of the overall RDI endeavour applicable to defence, and to ensure the principles of economy, effectiveness and efficiency in the investments of all parties. These actions are consistent with the guidelines included in the recently approved National Defence Directive (DDN 2020) and the Defence Policy Directive (DPD 2020), and contribute to achieving the objectives included in these documents.

This Strategy is therefore an important and ambitious initiative which, to the extent that it succeeds in achieving its objectives, will benefit the strengthening of national defence and the development of the technological and industrial base, and society in general.

I would like to conclude by thanking all those who have been directly or indirectly involved in the preparation of the Strategy for their support, especially the staff of the Under-Directorate for Planning, Technology and Innovation, responsible for the coordination and preparation of the ETID, for their dedication and enthusiasm in the service of this project, which will guide the RDI activities of the Ministry of Defence and, as the Secretary of State for Defence reminds us, will be applicable to the entire Department.

General Director of Armament and Materiel

# Contents

# 1. Ministry of Defence RDI policy

The RDI policy of the Ministry of Defence, under the responsibility of the Secretary of State for Defence, helps to achieve the objectives set by the Defence policy and therefore contributes to attaining the necessary capabilities of the Defence planning process, regulated by Ministerial Order 60/2015, of 3 December.

This public policy is subject to the framework established by Law 14/2011, of 1 June, on Science, Technology and Innovation, and therefore any action must be taken within the framework of the Spanish Science, Technology and Innovation Strategy (EECTI 2021-2027)[1] as a reference instrument for achieving the general objectives shared by all the public administrations competent to promote scientific and technical research and innovation.

Based on this regulatory framework, the RDI policy of the Ministry of Defence has been drawn up to promote the development of technological capabilities by the sector's stakeholders – which will be referred to throughout this document using the abbreviation for the Technological and Industrial Base (TIB) – with the ultimate aim of guaranteeing that they can sustainably maintain the capacity to supply the Ministry of Defence and its Armed Forces with the most technologically advanced systems and equipment, thereby enhancing military capabilities and contributing to the success of operations.

## Mission, vision and values

The defence RDI policy therefore pursues two basic objectives:

- Contributing to the development of military capabilities, providing advanced technological solutions that help achieve the principle of operational advantage in their use.
- Contributing to shaping the national technological and industrial base so that it has the necessary and essential capabilities for defence, in order to achieve the principle of freedom of action in the use of military capabilities.

These objectives make up the main **mission** of defence RDI, with which the specific objectives established in this Strategy, as well as the plans and programmes drawn up for its development, must be aligned.

The **vision** focuses on having a defence RDI system capable of leveraging both the Department's own capabilities and resources and any external opportunities it can access through national and international cooperation, acting in all the technological fields that are relevant to the missions of the Armed Forces and at different technology readiness levels, so that the results can be integrated into the processes of procuring future weapon systems and the

[1] https://www.ciencia.gob.es/stfls/MICINN/Ciencia/Ficheros/EECTI_2021-2027_EN.pdf

national technological and industrial base can provide a sustained response both to current technological needs and to the technological challenges that the future holds.

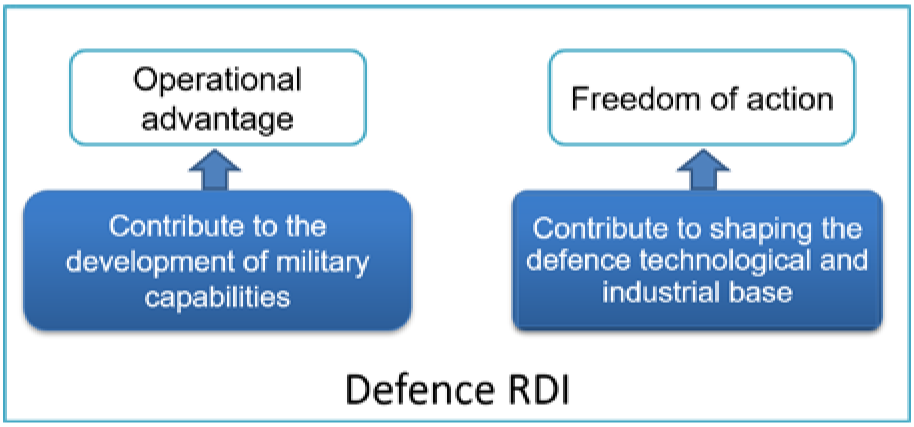


Figure 1. Defence RDI objectives.

The **values** of defence RDI permeate all its actions and contribute to addressing many of the challenges facing our society.

| | |
|---|---|
| Responsibility to the Armed Forces | - Vocation of service to the Armed Forces |
| Responsibility to other national public funding agencies of scientific and technological research | - Common commitment to support the development of the national technological fabric and economic growth |
| Responsibility to the Spanish TIB | - Equal opportunities for all kinds of entities<br>- Receptiveness to innovative ideas and proposals that promote technological progress in the Armed Forces. |
| Responsibility to society | - Contribution to the major security and sustainability challenges facing society<br>- Transparency in actions<br>- Use of public resources according to the principles of economy, effectiveness and efficiency<br>- Ethical principles as an integral part of all actions |

Defence RDI is characterised by a markedly applied and targeted nature, where the aim is always to transfer the latest technological advances to the current and future systems that contribute to the development of military capabilities. This link between RDI for defence applications and end systems conditions the way in which all actions are conceived and developed, regardless of the technology readiness levels (TRL[2]) from which they start and which they wish to attain.

[2] Technology Readiness Levels. This concept, as well as others used throughout this document, is addressed in Appendix C.

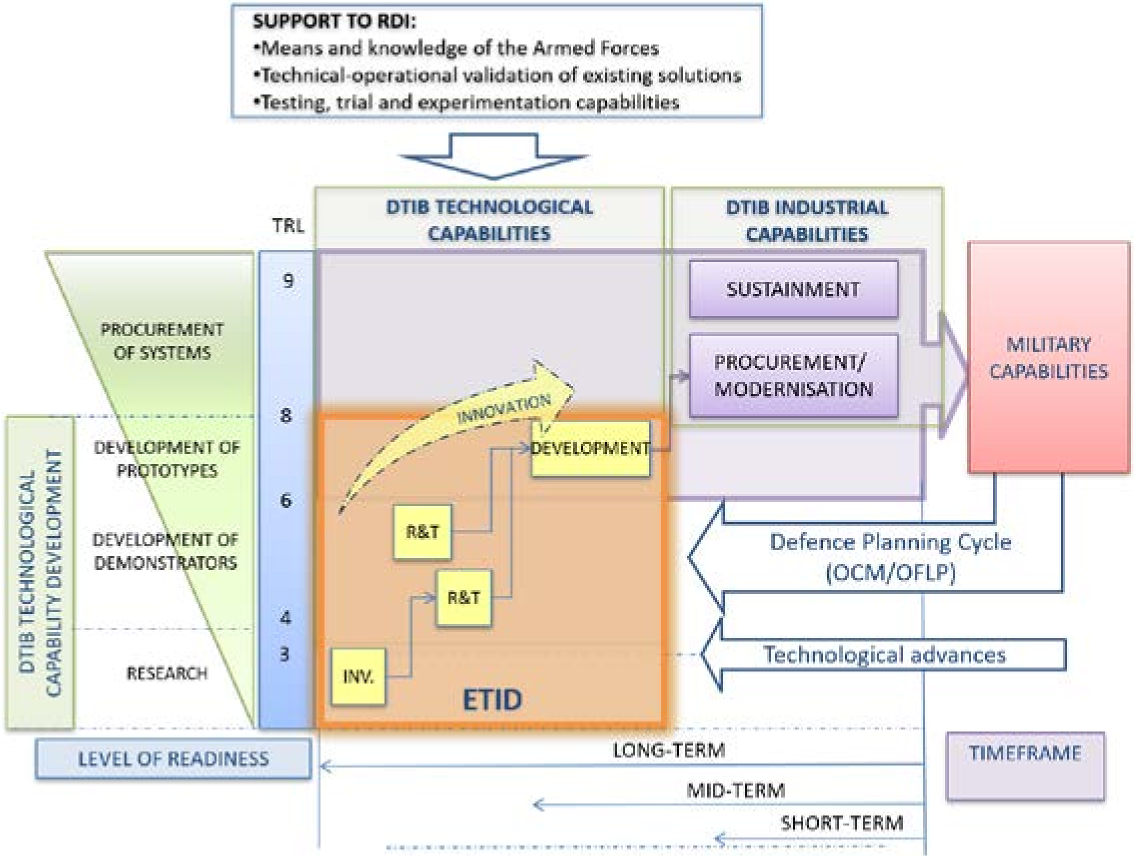


Figure 2. Defence RDI

Defence RDI is also integrated into the Spanish Science, Technology and Innovation Strategy, a framework instrument that establishes the general objectives linked to the promotion and development of RDI activities in Spain, takes their principles and objectives on board and develops them for the defence sector.

In this context, the actions of the Ministry of Defence are generally aimed at addressing defence needs that involve major technological challenges through the adaptation of existing technological solutions, as well as the development of technological niches where private activity does not meet the specific needs of defence, avoiding duplication with civilian RDI.

# 2. Current situation and trends in defence RDI

Addressing a strategy, which allows progress to be made from the current situation to the future established in the vision of the RDI policy, implies understanding the starting point and identifying the internal and external conditioning factors, as well as the obstacles and challenges that will have to be overcome to reach that end point.

In the case of the Defence Technology and Innovation Strategy, this analysis will first be carried out by considering the three main dimensions that guide the choice of the specific objectives that will mark RDI policy: military capabilities, technology and the stakeholders of the defence RDI ecosystem, including in this category TIB entities, other agencies responsible for organising or funding national RDI, international organisations linked to defence RDI, and the Department itself, which plays a central role as the director and coordinator of RDI in the defence sector.

It should also be pointed out that there are two variables that will condition the level of ambition of the actions of this Strategy:

- Timeframe. In the case of this Strategy, a six-year timeframe is established, aligned with the Defence planning cycle, although its applicability is two years out of synch, since the provisions of this document can only be governed by the General State Budget for 2021 and subsequent years.
- Financial framework. This Strategy will take as its starting point the scenarios included in the forecasts of the financial resources planning landscape, and the economic planning used to draw up the Military Capability Objective (CMO) and the Long-Term Force Objective (OFLP) in the definition phase of the Defence planning cycle.

## Military capabilities

The global context in which the Armed Forces operate is characterised by regular and frequent changes and transformations, which makes it necessary to constantly update military capabilities. Various studies[1] that attempt to explain the extreme environments and conditions in which the Armed Forces will have to carry out their missions today and in the foreseeable future characterise these operating environments in terms of volatility, uncertainty, complexity and ambiguity[2]. They are aimed at developing and consolidating new domains of confrontation in addition to the traditional physical domains (land, sea and air).

The first of these new domains, cyberspace, which cuts across all other domains, is already a worrying reality, gaining importance due to the increased globalisation and interconnection of

[1] *Operating environment 2035*. EMAD, 2019
*Panorama of geopolitical trends. Horizon 2040.* EMAD, 2019

[2] VUCA environments

systems and the low cost and significant impact of attacking the information systems of governments, companies, critical infrastructures or even weapon systems themselves. In connection with the foregoing, the cognitive domain emerges. This domain is linked to people's values and beliefs and is increasingly subject to manipulation or disinformation through campaigns in which false news or multimedia content that is difficult to detect is spread massively and instantaneously to alter the opinion or morale of large groups of the population, even affecting the governability of nations. And finally, outer space, where growing competition for space hegemony between the major powers converges with the presence of a growing number of actors, the latter due to the progressive accessibility and cheapness of space technology[3]. This combination can lead to conflicts that endanger space resources for observation and telecommunications, as well as to greater militarisation of space.

The tendency is for all of these domains to be increasingly interconnected, military operations being carried out in all of them within the principle of unity of action, and almost always simultaneously and continuously, providing multidimensional and comprehensive responses[4].

These forecasts also highlight the importance of enabling factors that can introduce new risks or threats to defence and security, or multiply and aggravate existing ones, such as the disintegration of political, economic and social systems, demographic imbalances, migratory pressures, unequal distribution of wealth, the struggle for natural and energy resources, the radicalisation of ideologies, regional actors capable of generating global instability, including fragile or failed states, climate change, natural disasters and pandemics[5], among others. The importance of some of these enabling factors is reflected in the commitment made by world leaders in 2015 to the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda. Spain has endorsed the priorities of this Agenda by approving the *Action Plan for the implementation of the 2030 Agenda: Toward a Spanish Sustainable Development Strategy*[6].

Moreover, it is suggested that conflicts will be increasingly asymmetric and hybrid, involving sovereign states, acting in accordance with international law, confronting the actions of terrorist groups that do not respect boundaries, not even where the use of weapons of mass destruction is concerned. They will often take place in more complex geographical scenarios (e.g., densely populated urban areas, coastlines, mountainous areas, cross-border areas, underground, extreme climates, etc.), which will greatly condition the usefulness of the means available and the way in which operations are approached, in addition to the many ethical and legal aspects present in these operations, which set limits that will need to be adapted to.

Many of these factors, together with the new possibilities offered by technological progress, will significantly condition the nature, characteristics and performance of the systems and equipment expected to be used in these future missions. This demand for military capabilities, which

[3] This ease of access to space is explained by the "New Space" concept, understood as a new business model for space activities, whereby private companies seek to develop new markets through the creation of space applications not considered so far by government agencies and traditional companies, such as space tourism, colonisation of other planets and asteroid mining, among others.

[4] The term «multi-domain operations» is often used to refer to this comprehensive approach of the battlefield, integrating capabilities from different domains, based on interoperability and hyperconnectivity.

[5] A clear example has been the pandemic associated with the COVID-19 disease that emerged at the beginning of 2020.

[6] https://www.agenda2030.gob.es/home.htm

involves major technological challenges if it is to be met, constitutes the principal reference that will guide the main defence RDI efforts in the years to come.

The Chief of Defence Staff (JEMAD), assisted by the Joint Defence Staff, is responsible for determining the required military capabilities and their prioritisation through the Defence planning process. He also establishes the medium and short-term needs of the Armed Forces, and the Long-Term Force Objective.

All military capabilities are included in “MIRADO-I”, the acronym in Spanish for materiel, infrastructure, human resources, training, doctrine, organisation and interoperability. The RDI referred to in this Strategy is geared toward the materiel aspect of military capabilities. However, this needs to be developed in a broad perspective and in coordination with the other MIRADO-I factors, to avoid unbalanced development of military capabilities.

In order to gain a better understanding of the Department’s interest in promoting certain RDI lines, just some of the main trends that will condition the evolution of these types of capabilities are outlined below:

- Growing use of remotely piloted systems (land, sea and air) which are increasingly sophisticated and autonomous, operating cooperatively or as part of a system-of-systems. Some of them, the smaller, low-cost and rapidly deployable ones, can create swarms that are difficult to neutralise.
- Huge growth in the number of deployed sensors interconnected on networks[7], capable of providing large amounts of data, the usefulness of which will depend on the ability to use it in an agile and intelligent way and correlate it with other multiple sources of information, if clear situational awareness is desired. This highlights the growing importance of the Internet and social media as sources of data for intelligence, although this domain is subject to manipulation and disinformation.
- Increased reliance of platforms, armament and soldiers on the availability of robust and resilient positioning, navigation and timing (PNT) communication and signal means, available at all times and in all places, even in increasingly congested electromagnetic environments.
- An increasingly complex electromagnetic spectrum that is more likely to be denied through the use of more sophisticated electronic warfare systems.
- The need to protect all systems against cyber-attacks, due to the increasing connectivity between all of them and their high software component.
- The need to physically protect all systems against increasingly lethal weapons, with shorter cycles between target detection and destruction.
- Outer space, already a new operational domain, where sensors and communications systems – and possibly weapon systems in the future – are rapidly being deployed.
- The performance of soldiers on the ground will continue to be a key element for the full control of crisis scenarios. Improvement will therefore be seen in their protection against all types of threats and in the enhancement of their capabilities. This will be achieved through new simulation techniques for their readiness and the multiplication of their effects in the operation.
- Emergence of new types of directed-energy weapons – in some cases displacing conventional weapons – which will be deployed in fixed installations to protect airspace or inte-

[7] Also known as the *Internet of Military Things*.

grated into platforms in all their areas of operation. Such weapons will undoubtedly pose a serious threat to platforms due to their effects on on-board software and electronic systems.
- Increased likelihood of using stakeholders of all kinds against forces and civilians. It is therefore necessary to improve means of detection, identification, monitoring and protection against CBRN and improvised explosive-based threats.
- Importance and care in avoiding any collateral damage in operations that could undermine their legitimacy; this leads to improved accuracy of conventional weapons.
- Minimisation of the environmental impact of Armed Forces activity in low and medium intensity missions, for which new forms of energy generation, storage and management will be developed, both on platforms and in fixed installations.
- The diversity of platforms and equipment and the projection of the Force in increasingly distant and disparate scenarios will make the work of logistics systems more difficult, and new technological advances developed in other areas of society (e.g., additive manufacturing, digital twins, etc.) will be sought to respond to the problems posed by these increasingly demanding forms of activity.

To summarise the foregoing, the outlook for the coming years is one that will require facing numerous challenges, vulnerabilities, threats and risks that are increasingly demanding and complex and in constant and rapid change. This will require a wide variety of very different systems, whose functionalities and performance will depend to a large extent on their technological component. This incorporation of technology into the systems used in defence is a fundamental, though not unique, element to achieve the freedom of action that the Armed Forces need in their missions and the political level needed in their decisions.

## Technological progress

The latest technological advances in areas such as artificial intelligence, big data, navigation and positioning technologies, robotics, the Internet of Things, social media, biotechnology, nanotechnology, additive manufacturing, new forms of energy storage, new materials and computing and communications are already bringing about a real revolution to which the defence sector is no stranger.

Such progress is largely due to the huge investment drive of the consumer society, especially in areas such as electronics or information and communication technologies (ICT), and also due to research and innovation efforts promoted by major countries, international organisations, universities, research centres and companies. The paradigm shift that has been taking place in recent decades, in which technological development aimed at defence purposes has been losing ground to technological development for civilian purposes, has therefore been consolidated. This is very positive, as it helps to improve people's quality of life and the advancement of society, while helping the Armed Forces to avail of more technologically advanced means that enable them to carry out their missions effectively and safely.

In this context of change, it is worth highlighting, in particular, the growing interest in so-called disruptive technologies or innovations[8], i.e., technologies that imply a radical change

[8] *Science & Technology Trends 2020-2040. Exploring the S&T Edge.* NATO Science & Technology Organization.

in the way of doing things, the occurrence and effects of which are difficult to foresee. From the point of view of companies, the emergence of one of these innovations can lead to either a dramatic increase in turnover or being driven out of the market. In the military field, their introduction implies a profound change in the way armies carry out their missions, reaching performances that would be difficult to attain through incremental innovation, which can lead to strategic surprises that are very difficult to control if steps have not been taken to anticipate them.

Present-day relevant examples of this are the use of remotely piloted aircraft systems (RPAS), which are revolutionising both military operations and many civilian activities; additive manufacturing, which is set to change manufacturing methods and logistics; and artificial intelligence, which in a few years promises to provide very significant capabilities in applications such as the automatic analysis of sensor data, platform maintenance, decision support systems, etc. And, taking a longer-term view, advances in quantum technologies, directed-energy weapons, synthetic biology or hypersonic vehicles could completely transform the defence and security threat landscape as we know it.

However, the use of new technologies also introduces uncertainties and vulnerabilities related to both purely technical (e.g., lack of clarity about the logic behind the decisions of AI-based systems, etc.) and ethical and legal aspects (e.g., limits on the use of biotechnology, building systems with increasing autonomous capabilities[9], among others). Such advances are also exploited by terrorist organisations that, thanks to the increasing ease of access to technology and knowledge on a global scale, are able to equip themselves with low-cost means to cause terror and destruction, which balances out their theoretical technological disadvantage and requires the development of novel technological solutions to help neutralise these new threats.

Despite such risks, these new technologies are conducive to achieving increasingly advanced and smart functionalities, something that cannot be foregone. Consequently, the central idea behind the Department's actions regarding technological progress is to leverage it to improve military capabilities, especially if this development involves disruptive advantages, anticipating the possible uses that enemy forces and terrorist groups may make of these same technologies, at all times within the framework of the legislation in force and the ethical commitment of the Ministry of Defence to society.

Given this scenario of change, an underlying question is whether the way in which technological progress has been approached from defence RDI is appropriate to tackle the challenges of the coming years and even decades. In this regard, some authors, referring to models that endeavour to explain technological progress and innovation[10], point to different ways of approaching RDI in the defence sector, to achieve advances in disruptive technologies. Specifically, as opposed to more traditional approaches (e.g., corrections and improvements to in-service systems, incremental evolution of more traditional systems, etc.), which generally involve less risk and have less chance of causing disruption, they point to the importance of gearing part of the

[9] "A hot topic of study, which raises controversy from ethical, legal and political points of view, is the level of autonomy that lethal autonomous robots (LAR) should have." *Operating environment 2035*. JEMAD 2019.

[10] *Disruptive Innovations to Help Protect against Future Threats.* Ernest Y. Wong and Nicholas M. Sambaluk. Inaugural U.S. based International Conference on Cyber Conflict.

RDI effort towards completely novel technological solutions, which have a greater capacity to redefine the market, but which also imply a high risk of failure. It is a matter of acting proactively in two directions:

a) Innovative use of technologies that are already mature. This involves putting into practice a novel idea that combines various mature technologies[11], causing an enormous impact on the sector in which it is applied. It does not involve radically new or complex RDI activities, nor does it involve major investment, as the results are obtained in the short or medium term. This is the type of innovation that is having the greatest impact on different sectors in the civilian sphere (transport, communication, etc.) and is also used by terrorist groups, which take advantage of commercially available technology to cause maximum destruction.
b) Advances associated with the development of emerging technologies. These are advances based on very complex ideas using technologies that are not yet mature, which imply a great deal of uncertainty but in turn promise to provide radically new or revolutionary benefits. They require intensive RDI efforts, with investments that only a few countries or corporations are capable of undertaking. Results come in the long or very long term, which can help to anticipate them. However, it is very difficult to fully understand the possibilities of these still emerging technologies or the timeframes in which they will actually be consolidated.

With regard to the innovative use of mature technologies, in recent years many countries and international organisations linked to defence have promoted open competitions to test technological solutions against highly complex realistic or simulated scenarios (challenges) or idea competitions to encourage the identification of new disruptive developments[12]. Some countries have even set up specific units dedicated to identifying disruption in the most innovative ecosystems[13] or use contractual approaches that, once an innovative idea has been identified, promote the rapid development of a prototype that can be tested in conditions close to the operating ones, to obtain feedback on its usefulness and possibilities as soon as possible. These are examples that can serve as a reference to promote similar approaches at national level.

In relation to the advances associated with emerging technologies, their development makes it necessary to involve all national research groups, as well as to promote RDI projects that enable these groups to reach a sufficient level of technological capability to participate in international defence-oriented cooperation projects, in which these novel, highly complex and high-cost solutions are addressed. In this regard, there has traditionally been a certain disassociation in Spain, possibly greater than in other European countries, between the scientific community and defence-oriented projects, which has limited our positioning as a country in the defence and security scenarios that are foreseen for the coming decades. It is therefore necessary to take steps to reverse this type of self-limitation, by providing adequate impetus to the national scientific and technological fabric.

In short, the scenarios for the coming years are very uneven in terms of the pace of technological progress. On the one hand, there are some still emerging technologies that promise to radically

[11] Often referred to as converging technologies.

[12] For example: NATO Innovation Challenge; EDA Defence Innovation Prize, etc.

[13] This is the case of the US Defence Innovation Unit.

change many different fields, including defence, and this makes it advisable to be prepared. In other cases, the commercial availability of low-cost technology offers new operational possibilities through its innovative use in defence, but at the same time facilitates its use for terrorist purposes. There are also cases in which the performance of civilian technology is less demanding than that required by defence, which makes it necessary to launch initiatives to promote its development until the required performance is reached. Nor should the need be forgotten to continue to carry out incremental improvement or evolution of in-service systems, as well as to participate in major development programmes for new land, naval or aerospace platforms that incorporate highly complex technological advances and require huge investments and very long development timeframes, but which often act as driving-force programmes for the technological capability development of very broad industrial sectors (NGWS, Force 2035, F-110 frigate, next generation transport helicopters, etc.).

The underlying idea is that there is no one-size-fits-all approach to promoting the incorporation of technologies into defence applications and that some of the technology management approaches used to date may need to be reformulated to address the different paces at which technology is currently advancing and the agility that is increasingly required.

This scenario challenges the processes and instruments of national RDI, and in particular those of the Department, which need to be increasingly agile, adaptable and able to anticipate change.

# Defence RDI stakeholders

## National technological and industrial base

Today's enormous technological progress is leading industry to a new industrial revolution, commonly referred to as Industry 4.0. As a result, structural and industrial changes and new possibilities for growth with a significant social impact are envisaged, entailing the associated opportunities and risks for the national technological fabric itself, depending on how it adapts to the new paradigm. At present, it does not seem easy to foresee what the industry resulting from this transformation will be like in one or two decades' time and, in particular, what the defence industry will be like.

The role of the TIB in the defence RDI process is fundamental, as it acts as a provider of the technological solutions required by the Ministry of Defence and as a link to transfer the technological development present in the civil sector to military applications.

In recent decades, a broad ecosystem of entities has been developing nationally, comprising different vocations and capabilities which, as a whole, complement each other. Thus, university departments and research centres provide the scientific support, both theoretical and applied, necessary to tackle technological challenges at low and medium readiness levels. Small and medium-sized enterprises contribute their ability to specialise and adapt to the change and innovation required by the current dynamic environment. Big companies contribute, among other things, their ability to tackle large programmes on a sustained basis, covering multiple technological areas simultaneously, and therefore have a special interest in tackling more mature technological developments. Finally, business associations and clusters also play an important role as a vehicle for fostering relations between companies and dialogue with Public Administration.

Greater collective awareness of the importance of RDI as a driver of growth and development for companies and societies is favouring increasing levels of public and private investment at national and European level, which suggests that this innovation ecosystem will continue to develop.

The defence sector is a cutting-edge and highly demanding technological sector that requires the continuous development of RDI activities in order to be competitive. The complexity of military missions and the extreme harshness of the environments in which they take place require the development of technologically advanced, high-performance systems.

This is a favourable environment for universities and research centres to produce advances in knowledge and technology, and for big companies and SMEs to find niches in which to focus their activities and expand the markets to which they can transfer their products.

It is therefore important to analyse the obstacles that hinder the participation of these TIB entities in the development of defence RDI, so that the Department can propose mechanisms or instruments to overcome them and thus facilitate the implementation of the actions necessary for the development of the technological objectives set out in this Strategy.

Undoubtedly the first obstacle or difficulty that the national TIB entities face in developing the technologies needed for defence is funding, particularly if they are at intermediate levels of technology readiness, where the possibility of recovering commercial returns is still far off, or if they are involved in technological areas of interest that involve major investments or in which national capability is very reduced, which limits their possibilities of participating in European initiatives. Therefore, support through some level of public funding nationally or internationally is an enabling factor for the development of these entities' capabilities.

However, a closer look at the problems faced by national TIB stakeholders reveals that funding, although an important aspect, is not the only problem, and that in some cases there are additional difficulties faced by companies that decide to carry out technological developments using their own funds.

The main obstacles identified in the development of technological capabilities of interest to defence by the TIB are:

1. Access to information. Every six years the Ministry of Defence prepares its Defence planning cycle, which gives rise to two documents: the OFLP and the OCM. However, due to the security classification criteria of these documents, this information is not public. Therefore, the TIB does not have details of what military needs will be in the short, medium and long term and its investments may not be consistent with the needs of the Armed Forces.
2) Access to requirements. Delving deeper into the problem of the difficulty of accessing and ascertaining the available information, even when the need to replace weapon systems due to their obsolescence is evident, all the requirements formulated in operational, functional, technical, logistical and physical terms that these systems must meet is not available in detail. As a result, TIB developments might not meet these requirements and, consequently, may not be of use to the Armed Forces.

Access to data can be included in this group when it is relevant to the design of solutions, such as in the case of systems that include artificial intelligence.

3) Access to test means. Certain technological developments require test facilities that are only available in the operational units. Examples of such means are launchers for the development of guided munitions units, or the munitions themselves.
4) Access to operational validation environments. The validation of developments in operating environments, including prototypes and demonstrators, and their testing in real-life exercises, is another obstacle that often hinders technological advances in the defence sector.

Therefore, in order for the national TIB entities to effectively and efficiently aim their RDI at the defence sector, it will be necessary to avail of appropriately sustained funding over time, instruments to overcome the aforementioned obstacles and favour the TIB's knowledge of current and future defence technology needs, and evaluation of developments by the Armed Forces' operational units.

## Spanish Science, Technology and Innovation System

Law 14/2011, of 1 June, on Science, Technology and Innovation, establishes the framework for the promotion of scientific and technical research and its instruments of general coordination throughout the national territory. Articles 6 and 7 of this law provide for the Spanish Science, Technology and Innovation Strategies as instruments for achieving the general objectives established in the law itself.

The timeframe of the ETID will coincide with that of the Spanish Science, Technology and Innovation Strategy for the period 2021-2027, as well as with the State Plans for Scientific and Technical Research and Innovation (PEICTI) for the periods 2021-2023 and 2024-2027, which will transform the objectives of the Strategy into specific actions and investments. The ETID falls within the framework of the EECTI 2021-2027, through the mechanisms and criteria for the coordination of the EECTI with the government's sectoral policies.

In addition, other national strategic initiatives that focus on the development of disruptive technologies and on the guiding and incentivising effect of RDI funding tools are also worth noting. Possibly the most relevant, and with the most synergies for defence, are the RDI Strategy on Artificial Intelligence[14] and the National Strategy for Connected Industry 4.0[15].

Within the framework of the EECTI and other national strategies that may be approved, there are different RDI funding instruments managed by State or regional bodies, which have traditionally excluded defence-related projects. However, the increasingly cross-cutting nature of technology and the duality of its application means that a significant part of these RDI efforts can be transferred to defence applications; this is of particular interest to companies from the national technological fabric, which see an increase in their possibilities for growth and development and can find new market and export niches in the defence field.

[14] https://www.ciencia.gob.es/stfls/MICINN/Ciencia/Ficheros/Estrategia_Inteligencia_Artificial_EN.PDF

[15] https://www.industriaconectada40.gob.es/Estrategias-informes/Estrategia-nacional-IC40/Paginas/de-scrip- cion-Estrategia-IC40.aspx

Both the DDN 2020[16] and the DPD 2020[17] stress the importance of the defence sector remaining at the technological forefront, reinforcing the Spanish TIB, with a clear European vocation, promoting RDI in coordination with other ministries and endeavouring to facilitate the duality of developments. Coordinated efforts must therefore be made among the public bodies responsible for promoting scientific and technical research and innovation in order to seek the necessary synergies to achieve an efficient use of the resources that society makes available for these public policies.

With this vision, the General Action Protocol between the Ministry of Defence, the Ministry of Science and Innovation (MCINN), the Centre for the Development of Industrial Technology (CDTI) and the State Research Agency (AEI), signed on 23 April 2019, came into being, with the aim of supporting and promoting the development and inclusion of technology and innovation in the field of defence and security. It is now time, within the timeframe of this ETID, to promote the implementation of this instrument.

From a comprehensive approach, this protocol sets out ambitious objectives[18] that could provide the essential impetus that the defence technological fabric needs to develop its capabilities and options in order to compete on a European and international scale. It can also act as a multiplier factor for public investment in RDI, avoiding duplication and optimising management resources, while at the same time enabling investments to focus on projects of interest to the end users of the technology, i.e., the Armed Forces, increasing their chances of reaching the market.

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[16] One of the guidelines of the DDN 2020 states: “14. The strengthening of the national defence industry and the development of a European Defence Technological and Industrial Base will be a priority and the best way to ensure that the Armed Forces’ equipment remains at the technological forefront. The Ministry of Defence, in close coordination with other departments responsible for technology and innovation, will promote opportunities and projects for collaboration with the European defence industry in competitive conditions. It will also pay particular attention to the dual use and possible enabling role of these technologies for the overall benefit of society and for the maintenance and creation of high-quality employment. Spain must participate in key technological projects to increase the capabilities of the European Union.”

[17] Within the guidelines in the field of military capabilities, technology and industry of the DPD 2020, the following criterion is included: “Promote and facilitate innovation and dual developments in coordination with other ministries, mainly the Ministry of Industry, Trade and Tourism (MINCOTUR), the Ministry of Science and Innovation (MICINN) and the Ministry of Finance and Public Administrations (MINHAP), operational requirements permitting.”

[18] The objectives of this General Action Protocol include the following:

1. *Provide guidance to the national technological and industrial fabric in all matters relating to technologies of potential dual use and, in particular, with regard to the trends of greatest interest in response to the medium and long-term technological needs of the Spanish Armed Forces and the potential channels for the support and funding of projects, in order to reinforce their technological and innovation capabilities.*
2. *Coordinate and, where appropriate, complement support for RDI activities of interest to the different parties, so that entities with ideas or projects receive adequate and coordinated support, enabling Public Administration resources to be optimised with the ultimate aim of ensuring that RDI investments reach the market.*
3. *Jointly develop strategies and development plans for specific technologies of potential dual use (civilian and military), both emerging and with greater readiness, to avoid or mitigate technological dependence on the outside world.*
4. *Work jointly and in coordination to defend national interests with regard to the participation of Spanish industry in international research, development and innovation programmes, particularly within the framework of the EU.*
5. *Collaborate in the promotion of results and advances in technologies considered to be of mutual interest by the national technological and industrial fabric, both those whose development is exclusively national and those carried out in cooperation with a foreign entity or organisation.*

This cooperation channel is also a reference for achieving greater interaction with the Autonomous Community bodies responsible for the technological and industrial development of their regions, taking advantage of the convergence between their Smart Specialisation Strategies[19] and the technological interests of defence.

## The European Commission and other international organisations

As is the case at national level, where the Chief of Defence Staff guides the military capability development process with his contribution to the OCM and the OFLP, those capabilities that are developed in the areas of international cooperation must be guided by the corresponding capability determination mechanisms and their priorities.

At EU level, these will be the Headline Goal Process (HLG), led by the EU Military Committee (EUMC), and the Capability Development Plan (CDP), led by the EDA. Both will actively involve Joint Defence Staff (EMACON) representatives to ensure consistency with national planning. The RDI activities of this Strategy, integrated into the corresponding actions in the field of international cooperation, should be guided by the aforementioned mechanisms so that investment supports defence priorities.

European initiatives such as the Permanent Structured Cooperation (PESCO), which creates the appropriate framework for European collaborative capability development projects, create additional opportunities for Spanish industry to collaborate with other European partners through the European Defence Fund (EDF).

The launch by the European Commission of the European Defence Action Plan (EDAP) in 2016, in the wake of the European Union Global Strategy (EUGS) of the same year, was geared toward contributing to the establishment of an innovative and competitive European technological and industrial base capable of responding to European defence needs and will continue to have a fundamental influence on European cooperation in defence R&T.

As a key part of this plan, the EDF includes a “window” or research dimension (EDF-R), which contemplates European Union (EU) funding of 100% for collaborative research in defence technologies, taking into account the lessons learned from the Preparatory Action for Defence Research (PADR), which took place from 2017 to 2019 (although the implementation period for projects launched thereunder will logically extend further in time).

In parallel to the research dimension, the EDF also includes another “development” or “capabilities” window, focused on developing systems with higher TRLs and prototypes close to achieving a military capability. This part of the EDF will take into account the experience gained in the previously preparatory programme, the European Defence Industrial Development Programme (EDIDP), launched from 2019 to 2020.

Figure 3 summarises the range of new funding instruments that have been taking shape in recent years.

[19] S3 Strategies (Smart Specialisation Strategies). Integrated agendas for territorial economic transformation developed by both the State and the Autonomous Communities seek, among other objectives, to make RDI a priority for all regions, as well as to concentrate resources in the most promising specialisation areas of each region.

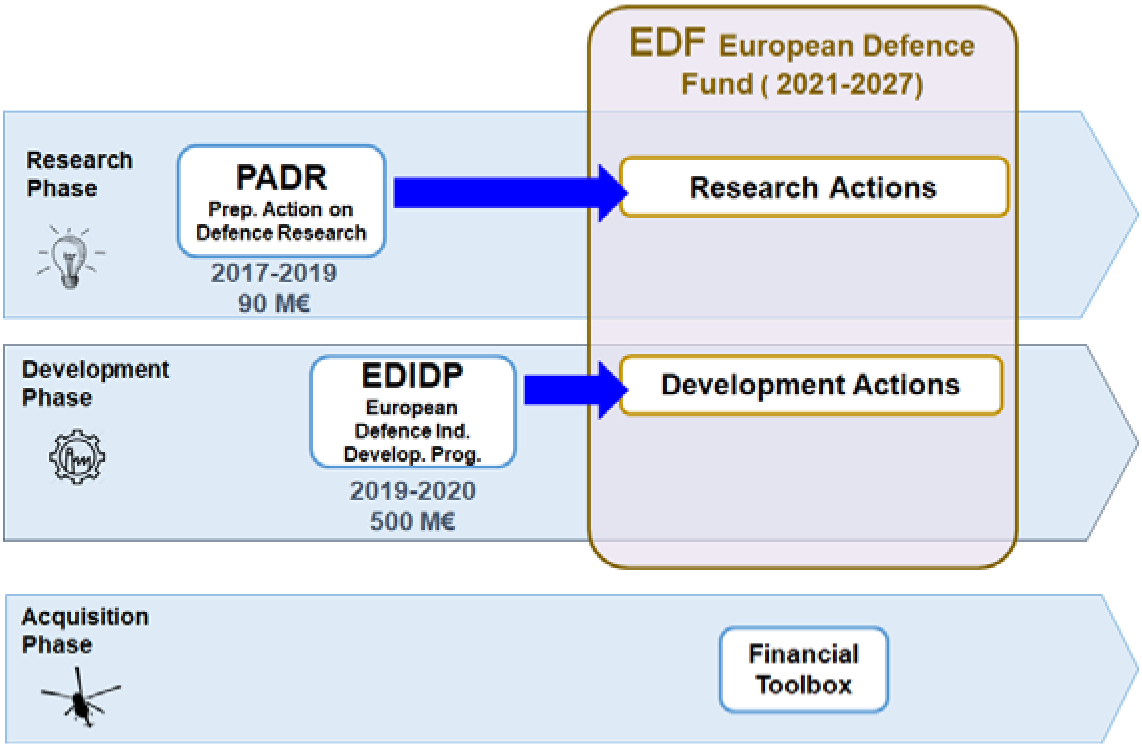


Figure 3. EDAP-associated instruments.

Since the EDAP initiative was launched, the Ministry of Defence, the CDTI and other relevant institutional actors have been working to establish new coordination and support mechanisms for the national technological and industrial base to promote its participation in calls for these types of European projects aimed at defence with maximum guarantees of success.

The High-Level Inter-Ministerial Committee on the Commission's European Defence Action Plan (EDAP) was set up for this purpose. This Committee, which coordinates EDAP-related positions, is led at national level by the Ministry of Defence, and all actors involved in this initiative, both inside and outside the Ministry of Defence, participate in it[20].

This Committee is supported internally in the Ministry of Defence by the Working Group on European Defence Initiatives (GTIED), in which all Department bodies with responsibilities in this area participate. This channel of European support for the European defence technological fabric was originally conceived to coexist with funding for the development of civilian or security-related technologies that have been consolidated in the last decade in the EU's framework programmes and which, in some cases, could also be of interest to defence.

Thus, in this area of dual-use technologies, the aim will be to participate in the calls for proposals of the Horizon Europe programme that are considered to be of interest to the Ministry of Defence in accordance with this Strategy, as well as to follow those of a more scientific nature with poten-

[20] In addition to representatives of the Ministry of Defence, this Committee includes representatives of the Ministry of Foreign Affairs, EU and Cooperation; Ministry of Economic Affairs and Digital Transformation; Ministry of Industry, Trade and Tourism; Ministry for Ecological Transition and the Demographic Challenge; Ministry of Finance; Directorate-General of the Treasury, Centre for the Development of Industrial Technology (CDTI), Spanish Association of Defence, Aeronautics and Space Technology Companies (TEDAE), Association of Contractors with Public Administrations (AESMIDE) and Engineering Systems for the Defence of Spain (ISDEFE).

tial for future defence applications that may be developed in this European programme. To this end, coordination with Ministry of Science and Innovation (MICINN) bodies such as the European Office, the Deputy Directorate-General for the Internationalisation of Science and Innovation, or the CDTI itself is particularly important.

The European Structural and Investment Funds (ESIF) are another major source of funding that could be applied to the development of dual technological research (R&T) activities of interest to defence. The ESIF mechanism is linked to the EU's Economic and Social Cohesion Policy, which aims to reduce economic and social disparities between the different regions of Europe. These funds can be used to finance projects related to research in dual-use technologies to improve and boost the competitiveness of regions, promoting economic growth, job creation and sustainable development. In the coming years, efforts will be made to take advantage of the opportunities offered by these funds to develop RDI projects of interest to defence.

There are two main organisations in the field of multinational cooperation in defence-specific research and technology: the European Defence Agency (EDA) and the NATO Science and Technology Organization (STO).

The EDA has a Steering Board comprising R&T Directors to specifically foster research and technology with our European partners, which resolves R&T issues at ministerial level within the Agency.

The purpose of R&T in the EDA is to contribute to the development of future European defence and security capabilities through cooperation between participating countries, which fund projects of interest to defence that involve the participation of entities such as companies, universities, research centres, etc. In practice, this cooperation between countries is mainly managed through the so-called CapTechs (Capability Technology groups), which comprise a network of governmental and non-governmental experts dedicated to designing strategies and exploring possibilities for collaborative activities in specific technological areas. In addition to the so-called Category A programmes and Category B projects, which are funded by Member States, there are also activities that the EDA launches from its operational budget, through tendering processes, for state-of-the-art review studies of a technological domain, or pre-feasibility studies, which typically serve to improve situational awareness of a technological field and explore research investment needs. The tenders are open to industry, research centres, and universities in the sector through a competitive bidding procedure, which is organised directly by the EDA and called OB studies[21].

In terms of strategy design, through the coordinated work of the CapTechs, the EDA has prepared the first edition of its Overarching Strategic Research Agenda (OSRA), and a series of associated roadmaps, in the form of a European defence research strategy to seek areas of interest for cooperation among its Member States and also with the aim of providing certain harmonised priorities for the European Defence Fund.

The OSRA information has been used as a reference in preparing this ETID, together with parts of other EDA-developed tools applicable to R&T, such as the Key Strategic Activities (KSA). The latter include aspects concerning industry, technology, technical capability-building of personnel, etc., which should be developed at European level. They derive from the Headline Goal

[21] All related information is available on the website www.eda.europa.eu

Process (HGP) and the High Impact Capability Goals (HICG), essential elements in EU defence capability-planning, which also guide research development.

It is thus expected that harmonisation of this aspect of international cooperation will be improved, bearing in mind that in 2018 the EDA initiated a process of regular review and collection of data on Member States' defence activities called CARD (Coordinated Annual Review on Defence). Among many other things, this process reviews each country's defence R&T activities and investments, including those carried out through European cooperation, in order to check trends in meeting the common objectives previously agreed upon by the Agency's Ministerial Steering Board, and explores opportunities for cooperation between Member States (pathfinder).

It is important to work to enhance coordination between the European External Action Service, the Commission and the EDA to strengthen collaboration.

Within NATO, the STO is the main reference framework for science and technology research with the aim of sustaining the Alliance's leading-edge knowledge and technology in the field of defence and security. The STO has two business models: the Collaborative business model and the In-house delivery business model.

In the Collaborative business model, the STO acts as a forum where nations use their resources to define, conduct and promote cooperative research and information exchange. This forum comprises 7 panels or groups of experts covering different technological areas (platforms, sensors, human factors, simulation, etc.). Each year, nations agree on a set of activities that are carried out across these 7 groups and form part of the so-called Collaborative Programme of Work (CPoW). These activities can take the form of technical research groups, symposia, workshops, cooperative technology demonstration events, training activities, long-range scientific studies, etc. Participation is generally open to actors from industry, research centres, universities, government, etc., and is channelled, upon their request and commitment to participate for the entire duration of the activities with their own resources, through the national coordination offices. Their results are often publicly available on the STO website[22].

In the in-house delivery business model, science and technology activities are carried out at the Centre for Maritime Research and Experimentation (CMRE) in La Spezia (Italy), which belongs to the STO itself and has its own staff and infrastructure, including two vessels with specific research capabilities[23]. The CMRE draws up its own annual work programme, independent of the CPoW.

## The Ministry of Defence

The Ministry of Defence is a complex organisation regulated by Royal Decree 372/2020, of 18 February, which is structured into bodies with different roles in defence RDI activities.

At the top of this organisation, assuming management roles, is the State Secretariat of Defence, which is responsible for the leadership, promotion and management of research, development

[22] www.sto.nato.int

[23] All relevant information, including access to many of the documents produced by the panels and the CMRE, can be found on the STO website (https://www.sto.nato.int).

and innovation policies in the field of defence, the General Directorate for Armament and Materiel being the management body responsible for planning and developing such policies, and for controlling their execution.

On the other hand, the Ministry of Defence has different organisations where research is conducted and RDI projects are carried out, in some cases as their main purpose and in others as a function associated with another basic purpose of the organisation.

This group of organisations, whose role in the Ministry of Defence is to carry out research activities and develop RDI projects, includes the *Esteban Terradas* National Institute of Aerospace Technology, an autonomous organisation attached to the State Secretariat of Defence, which, as a public research organisation (OPI), carries out dual scientific and technical research activities, as well as providing technological services.

Its main areas of activity are in the fields of aerospace technology, aeronautics, hydrodynamics and defence and security technologies, acting within the framework of the priorities set by the Ministry of Defence, and within the research, development and innovation guidelines determined by the aforementioned Department with the aim of maintaining unified action in relation to technologies with defence applications.

Similarly, the main purpose of the Defence University Centres (CUD), created by Royal Decree 1723/2008, of 24 October, in accordance with the provisions of the Military Career Law, is to provide the undergraduate university degrees referred to in the Law itself, while at the same time taking charge of defining and developing lines of research considered to be of interest to the Armed Forces in collaboration with other public educational and research entities and organisations, within the framework of security, peace and defence.

It should be noted that prior to the creation of the Defence University Centres (CUD), the Army and the Navy already availed of the Army Polytechnic School and the Higher Technical School of Naval Weapons Engineers, respectively, whose main purpose is to train the officers of their engineering corps, but where work is also carried out in lines of research of interest to the Armed Forces, especially in the doctoral studies of their officers.

There are also other bodies within the structure of the Ministry of Defence where research is conducted and RDI projects of interest to national defence are carried out.

On the other hand, as RDI is a cross-cutting aspect of all the Department's resources, coordination is necessary with the other management bodies responsible for policies whose development may require the promotion of RDI activities, under the guidance of the DGAM at all times. Thus, in the case of infrastructures, this coordination should be carried out with the General Directorate for Infrastructure (DIGENIN), while with regard to ICT aspects coordination should be with the Centre for Information and Communication Technologies and Systems (CESTIC), following in both cases the applicable infrastructure and ICT policies, as well as the guidelines of the Department's own RDI policy included in this Strategy, thereby focusing actions on technological challenges relevant to defence, without duplicating efforts with RDI for civilian purposes.

Finally, a very important role is played by the entire structure of the Ministry of Defence, in which the Armed Forces and the Defence Staff play a prominent part, as originators of military capabilities and end users of the results of research developments and RDI projects in the field of defence, being able to guide and validate technological solutions according to real operational needs, adding enormous value to the results of the projects and bringing them closer to the market.

The effective and efficient orchestration of all these resources and capabilities of the Ministry of Defence in an attempt to optimise the budget, coordinating actions with the mechanisms available in the State and regional plans derived from the EECTI, promoting opportunities for national cooperation, and seeking possibilities for collaboration at European and international level that do not undermine the development of our strategic technological capabilities, is a challenge of growing complexity and necessity for those responsible for planning, programming and controlling the implementation of the research, development and innovation policy within the Department.

Based on Order DEF/685/2012, of 28 March, which regulates and coordinates the research and development of weapon systems and equipment of interest to national defence within the Ministry of Defence, work needs to continue on optimising the planning, procurement and management processes of RDI projects, measuring the results of RDI activities and leveraging them to ensure effective and efficient use of funding.

It is also important to improve and extend the collection of instruments linked to the development of new technological solutions currently available, to adapt them to each technology readiness level and to the current pace of technological progress, to encourage the participation of all types of entities in the national technological fabric and to facilitate their complementarity with other actions of the State Plan for Scientific and Technical Research. This will make it possible to shorten implementation periods in defence of civilian technologies, following the approach of our European partners[24]. Work has been done along these lines in recent years with the review of instruments such as the programme for Cooperation in Scientific Research and Development in Strategic Technologies (COINCIDENTE)[25], or by lending greater weight to technical-operational experimentation activities on technological demonstrators and system prototypes, with a view to obtaining feedback on the possibilities and shortcomings of these developments in relation to their future military application[26], or by supporting the CDTI in the evaluation of dual-use projects.

On the other hand, the Ministry of Defence has traditionally paid great attention to international collaboration in RDI, which has been very positive for the interests of the Armed Forces and the

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[24] Some countries, such as France, have a collection of specific instruments (ASTRID, ASTRID Maturation, RAPID, etc.) aimed at RDI for defence or dual purposes that cover the entire spectrum of technology readiness levels. https://www.defense.gouv.fr/fre/dga/innovation2/innovation

[25] The «Cooperation in Scientific Research and Development in Strategic Technologies (COINCIDENTE)» programme aims to take advantage of technologies developed in the civil sector that can be applied in projects of interest to the Ministry of Defence. It is regulated by Order DEF/862/2017, of 28 August, which regulates the procedure for calling selection and procurement processes for R&D projects of interest to defence, within the scope of the COINCIDENTE programme. The R&D projects must be aimed at developing a demonstrator with military functionality and must involve a significant technological innovation that satisfies a real or potential need of the Ministry of Defence.

[26] Examples of this are the RAPAZ, CONDOR and BARRACUDA programmes, managed by the DGAM, or the Army's plans to carry out technological solution experimental activities, within the framework of its Brigade 2035 initiative. http://www.ejercito.mde.es/estructura/briex_2035/principal.html

TIB, although less attention and resources have been provided for national collaboration. The growing importance that this national RDI collaboration is acquiring makes it necessary for the Department to have sufficient capacity to harness the synergies that exist with the other State and regional bodies that fund civilian and dual RDI.

Another element that can serve as a catalyst for technological development in defence is the value of the Ministry of Defence's knowledge as the end user of the systems and its vision of the long-term technological needs. Given the applied and end-use nature of defence RDI, if this knowledge is not incorporated into projects, in many cases it will be difficult for the result to be aligned with real needs. This need to share knowledge makes it necessary to intensify efforts to exchange information with the entities that make up the TIB so that they are aware of these needs and can aim their RDI proposals in this direction, adapting the procedure in each case to the levels required by the regulations for handling classified information, where applicable.

It is also particularly important for the Armed Forces to be more involved in the RDI projects being undertaken, as future users of the technologies that are developed, to ensure their correct orientation toward real needs, in a way that guarantees their applicability and increases the chances of the results reaching the market.

In addition to its own knowledge of needs, in some technological fields it is important for the Ministry of Defence to facilitate specific resources to enable the development of RDI projects with defence applications. This is the case of certain military platforms, whose characteristics are so unique that it is often ineffective to develop RDI activity on substitute civilian platforms.

A paradigmatic case that has become increasingly important concerns the application of the latest advances in artificial intelligence based on machine learning, which have had such repercussion in recent years and will condition technological superiority in the coming decades. In particular, these techniques can alleviate the significant bottleneck that exists due to the growing number of sensors of all kinds deployed, which provide huge amounts of information that can hardly be analysed unless automatic or semi-automatic methods are used. The most commonly used techniques, supervised learning techniques (e.g., deep learning), require that, in addition to the data obtained from sensors (images, video, etc.), information about what an analyst would consider of interest from such media is fed into them, so that it can be used to teach algorithms to respond to new situations similarly to the way humans would. This implies that the Armed Forces analysts need to do some prior work on data tagging before any RDI project in this field can be developed. If this data collection is not approached systematically and comprehensively for each of the specific problems in which these techniques are to be used, it will not be possible to take advantage of the possibilities of this technology for the benefit of defence[27].

In short, it is necessary to carry out a series of actions within the Department that facilitate the development of RDI activities, so that the Ministry of Defence can act as a catalyst for the development of technology with defence applications and for the capability-building and development possibilities of the national technological fabric.

[27] This idea is also incorporated in the document entitled *AN ARTIFICIAL INTELLIGENCE WHITE PAPER FOR NATO: DYNAMIC ADOPTION, RESPONSIBLE USE,* which highlights the main issues that the Alliance should address in defining its approach to artificial intelligence.

# 3. Guidelines and actions

Achieving the future established in the vision of the defence RDI policy requires a series of technological and managerial actions to be carried out. As there are many possibilities for this path, guidelines need to be established to select the most appropriate actions that will contribute efficiently to achieving the objectives set out in this Strategy.

Based on this idea, which combines objectives and efficiency, and on all the possibilities offered by the Spanish Science, Technology and Innovation System and the opportunities opened up within the framework of international cooperation, the following guidelines are established:

— **The RDI activities promoted by this Department will be guided by technological objectives**, with a view to focusing efforts on issues that have a high impact on the improvement of current and future military capabilities, while optimising the use of available funding.

— **Technological cooperation at national and international level will be an essential part of defence RDI activities**, making it possible to take advantage of advances in dual RDI, achieving multiplier effects and also tackling high-cost and complex technological challenges.

— **Excellence will be pursued in the Department, through the continuous improvement of the processes associated with defence RDI**, in order for them to act as catalysts for technological advances in the Armed Forces and technological development in the defence sector.

These guidelines in turn constitute the three fundamental pillars that will underpin the RDI activities carried out or coordinated within the Ministry of Defence to achieve the objectives of the RDI policy.

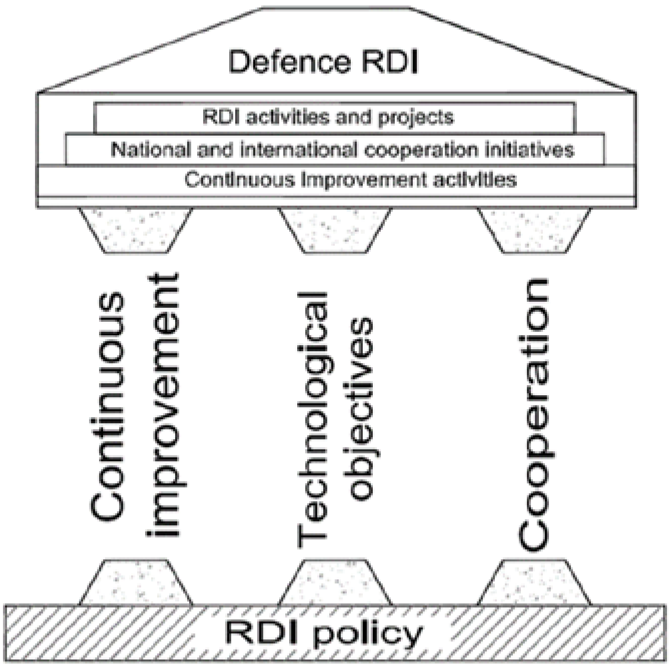


Figure 4. Guidelines for development of RDI policy.

## Technological objectives pillar

The wide variety of types of systems required in defence, the functionalities and performance of which depend to a large extent on their technological component, means that the Ministry of Defence's technological interests are very broad. Therefore, to gain a complete vision of these technological interests, the present Strategy includes a set of **RDI lines of interest to defence**, whose objective is the application of the latest technological advances in systems and subsystems designed to be used in defence, to improve their functionalities or create new possibilities for their operational use, thereby contributing to the development of military capabilities.

The definition of this concept is consistent with the applied and purposeful nature of defence RDI, in the sense of considering technology not as an end in itself, but as a means to improve military capabilities.

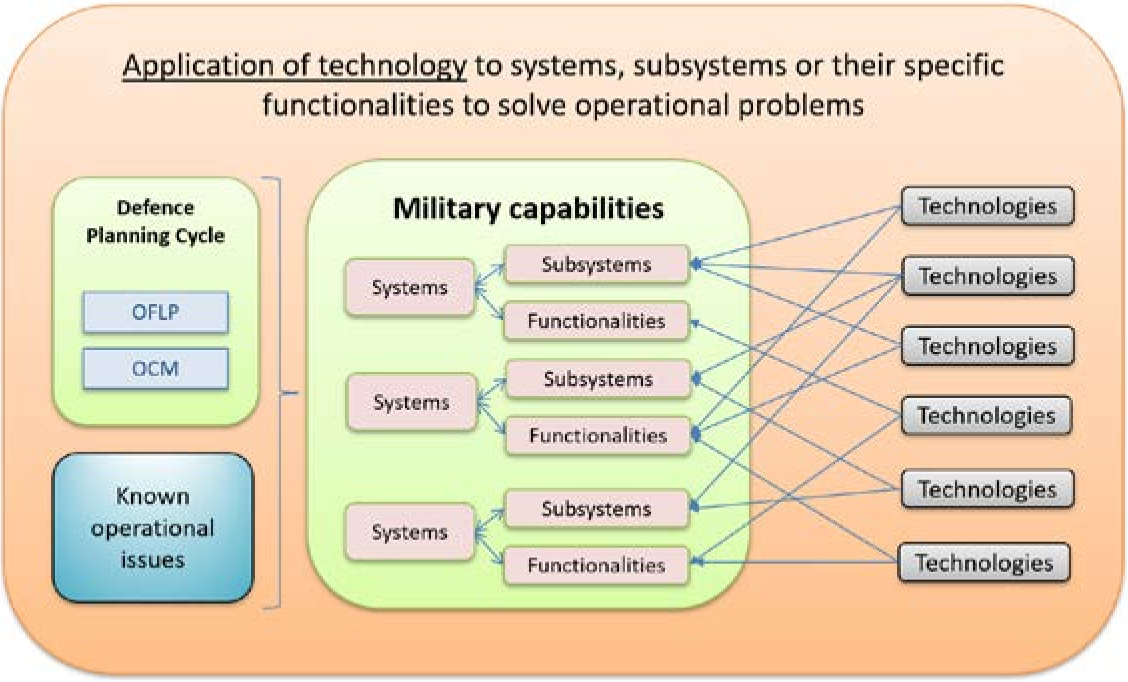


Figure 5. RDI of interest to defence.

These RDI lines, defined in Appendix A, serve as a reference to guide the Ministry of Defence's RDI planning, as well as to establish collaboration with other national and international stakeholders. They have been identified and defined from a triple perspective: military capabilities; technology; and TIB technological capabilities.

To address the dimension of military capabilities, the documents approved in the Defence planning process were used as a starting point, more specifically the OCM and the OFLP, along with other documents produced by the Defence Staff (*Operating Environment 2035* and *Panorama of Geopolitical Trends: Horizon 2040*), and the specific overview documents drafted in the environment of the Army, Air Force and Navy.

The technological dimension has been obtained as a result of the analysis of the foreseeable evolution of technologies, whether already consolidated or emerging, and their applicability to the processes or systems that make up a military capability.

Lastly, the analysis of the TIB's technological capabilities, which can largely condition the way in which each line is approached, was based on technology watch information, as well as other sources of knowledge available in the Department. In particular, this dimension considers the Defence Industrial Strategy 2015 (EID 2015), the main reference for guiding the efforts of companies and Public Administration with regard to the industrial component of defence, which establishes areas of knowledge that affect the essential interests of defence and security, based on an analysis of defence strategic industrial capabilities (CIED)[1].

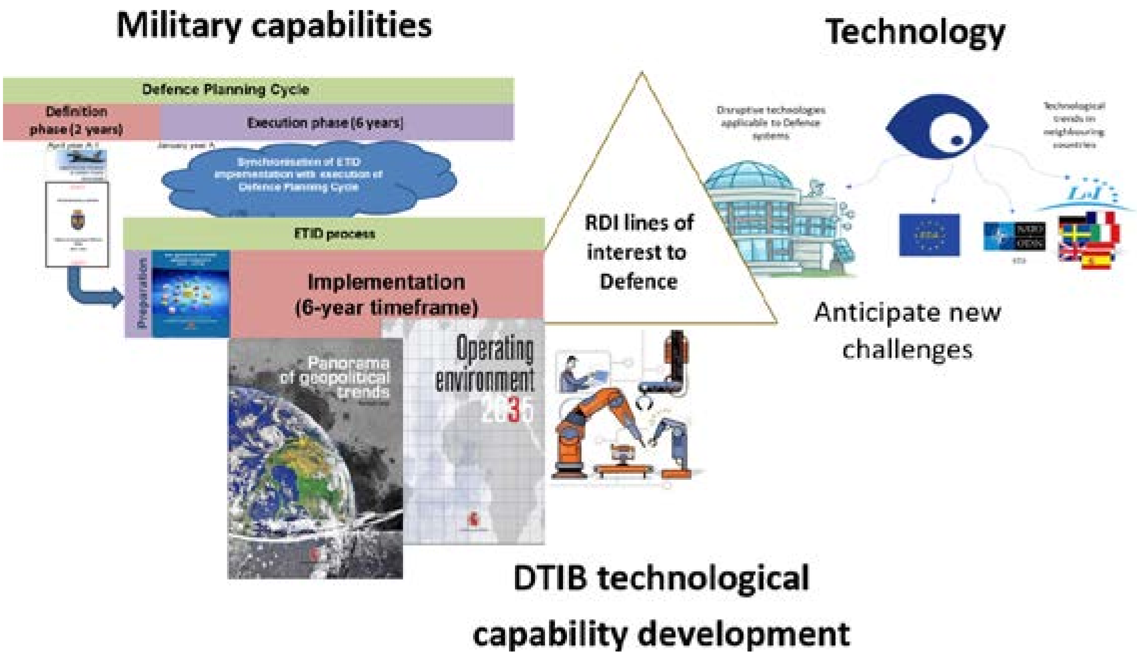


Figure 6. RDI lines of interest to defence.

Considering that there are many RDI lines of interest o defence,that there are limitations in terms of the possibility of funding all of them by the Ministry of Defence, and that there are many differences among them in terms of their potential impact on military capabilities, their technology readiness level, the technological capabilities of the TIB, or their possible dual uses, this Strategy prioritises a subset of these RDI lines, considering them to be **technological objectives** for the period of validity of the Strategy[2].

Most of the Department's RDI activities will focus on these technological objectives and specific plans will be developed for each one of them, thereby establishing attainable levels of ambition in the Strategy's implementation timeframe, which will coincide with the six-year development of the implementation phase of the Defence planning cycle, thus allowing for the alignment of both processes.

[1] Resolution 420/38100/2015, of 30 July, of the Technical General Secretariat, publishing the Agreement of the Council of Ministers of 29 May 2015, determining the industrial capabilities and areas of knowledge that affect the essential interests of defence and national security.

[2] This prioritisation of technological objectives is an important departure from previous versions of the ETID, in which the Ministry of Defence's technological interests were reflected through a broad set of unprioritised technological goals.

These plans will define RDI activities that will frequently combine the development of prototypes close to operational use with the development of technological demonstrators that provide the TIB with technological capabilities, together with other enabling actions for defence RDI, and may make use of any of the instruments promoted by the Ministry of Defence or be developed through national or international cooperation.

Bearing in mind the considerations in chapter 2 regarding scenarios with different rates of technological progress, the technological objectives of this Strategy are organised into three levels, depending on the size and characteristics of the systems and technologies involved and the type of actions envisaged for their achievement.

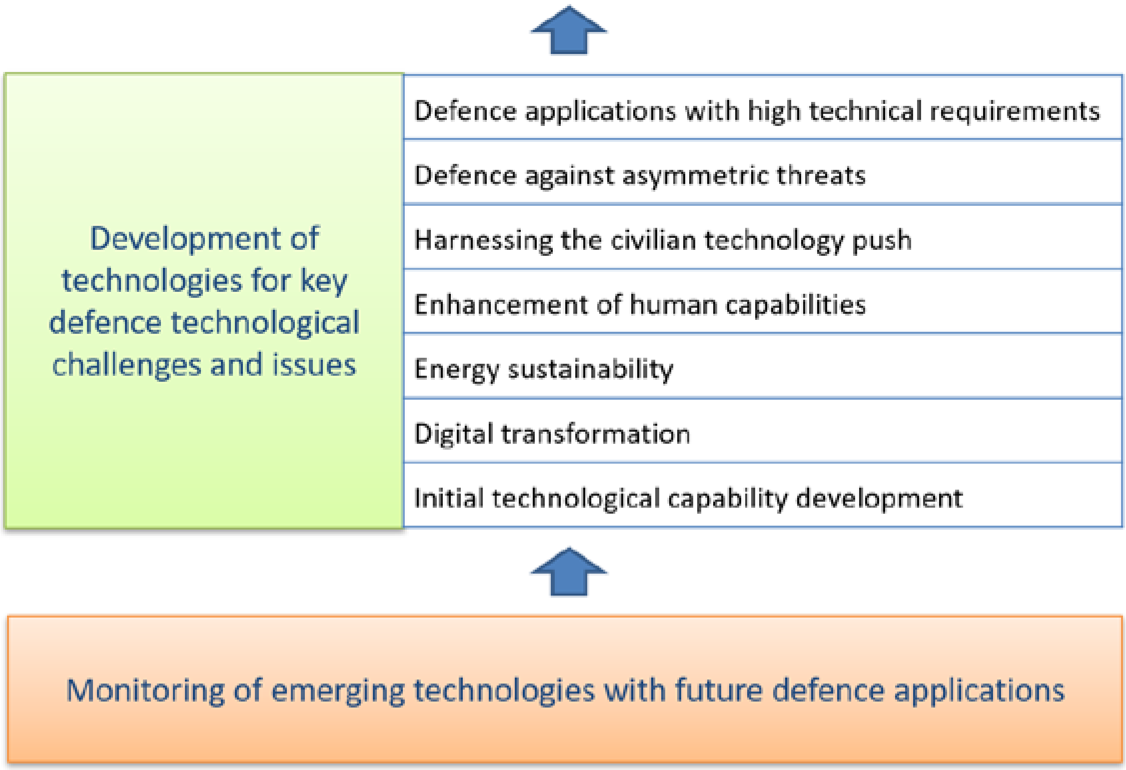


Figure 7. Organisational levels of ETID technological objectives.

The scope and purpose of these three levels, as well as the objectives they include, which are explained in more detail in Appendix B, are described below.

### A. Development of advanced technologies for incorporation into future major platforms and weapon systems

This higher level includes technology objectives aimed at promoting the development of technologies for incorporation into future major platforms and weapon systems to be used by the Armed Forces in their future missions, in the land, sea, air and space domains.

These objectives are derived from needs included in the Military Capability Objective (CMO) and the Long-Term Force Objective (OFLP), whose development acts as a driving force for technological capability development in very broad industrial sectors and is also a driver of quality employment in these sectors.

Given the nature of the threats the Armed Forces have to face, it is strictly necessary to avail of these types of major platforms and weapon systems, which are often built through international cooperation, involving significant financial investment and very long development timeframes.

As these systems are designed to be in service for decades, technological programmes must be undertaken a number of years in advance, in which the latest technologies are incorporated into the most critical functions of the system through technology demonstrators, thereby allowing the readiness of these developments and the risk of transferring them to the end systems to be validated.

The most representative programme at present is the Next Generation Weapon System (NGWS), in which Spain has been a partner since 2019, whose pillars comprise the New Generation Fighter (NGF), a series of unmanned Remote Carriers (RC) and new advanced sensor systems. It is expected that between 2035 and 2040 the various European fighters currently in service under the FCAS (Future Combat Air System) will be replaced by the NGWS.

Also in the aeronautical field, there are other opportunities related to the development of future rotary wing systems, in addition to others in the land domain (technologies for future land combat systems, Brigade 2035, for future low-level anti-aircraft defence systems, among others), in the sea domain (technologies for future naval combat systems) and in the space domain (technologies for future satellite systems).

To achieve these objectives, consideration is given to the projects in which Spain participates that are developed within the framework of international cooperation programmes, and the projects developed nationally that are applicable to these future major platforms or weapon systems.

These driving-force programmes are an opportunity for the development of strategic industrial and technological capabilities, and the government's decision to participate in them will lead to the drawing up of industrial and technological plans (PLANITEC) that will define the national industrial organisation in accordance with the capabilities of our industrial fabric, and will specify the capabilities and technologies to be developed within the framework of each programme.

### B. Development of technologies for key defence technological challenges and issues

This intermediate level includes technological objectives aimed at addressing the main technological challenges present in the most complex scenarios in which the Armed Forces have to operate, as well as taking advantage of current technological progress to develop new advanced and innovative solutions for defence.

The systems and subsystems targeted by these objectives are much broader and more varied than at the previous level although, in general, the technological developments in question are on a smaller scale than those addressed in the major programmes. However, in many cases, the progress achieved with these objectives can be the basis for the national TIB to participate in initiatives of greater scope at both national and international level, including the large driving-force programmes, contributing in line with the technological level expected of Spain.

These objectives were chosen for a variety of reasons, which are described below:

**1. Defence applications with high technological requirements**

Objectives aimed at enhancing typically military applications in which the operational constraints impose much more demanding requirements on the technology than those of civilian applications. These requirements, not necessary for civilian applications, require an investment effort by the Ministry of Defence which, in addition to the advantages for defence itself, could lead to new innovative solutions for the civil sector in the future.

**2. Defence against asymmetric threats**

Objectives focused on the development of technological solutions that protect both military personnel during operations and the population against asymmetric threats.

**3. Harnessing the civilian technology push**

Objectives derived from the technology push that is taking place in civil society regarding the use of certain technologies and the new possibilities that are opening up in their application to defence systems, which in some cases can have a disruptive effect on the current concept of operations.

**4. Enhancement of human capabilities**

Objectives that pursue technological progress to enhance military personnel's capabilities in operations, improving their training or multiplying its effects.

**5. Energy sustainability**

Objectives that seek to incorporate the Ministry of Defence in the fight against climate change and in achieving the UN Sustainable Development Goals, through the development of technological solutions that minimise the impact of military operations on the environment.

**6. Digital transformation**

Objective aimed at supporting the Department's digital transformation through technological innovation actions, leveraging advances in 4.0 technologies.

**7. Initial technological capability development**

Objectives geared toward supporting national TIB capability development in technological areas of significant future potential for defence – in general very high-cost ones – in which national capabilities are currently very limited or non-existent. The aim is to ensure that TIB entities are able to develop sufficient capability levels to respond to future demand for systems incorporating these technologies and encourage these entities to participate in international cooperation projects.

Each specific action area encompasses technological objectives, a detailed description of which is included in Appendix B.

It is important to stress that, although these technological objectives are considered to be of particular relevance for defence, the financial effort envisaged to promote the development of each objective differs, depending on the specific areas in which they are included. Specifically, aspects such as the possibility of dual use of the technological developments or their level of readiness will condition the financial resources that the Department plans to allocate to their development.

Indeed, progress on some of these technological objectives, such as those related to space, energy or CBRN, all of which have a strong dual-use component, is expected to rely heavily on sources of funding from outside the Department.

| Specific area of action | Technological objectives |
|---|---|
| Defence applications with high technological requirements | Munitions guidance and advanced control technologies |
| | High-performance electronic technologies |
| | Electronic warfare solutions adapted to the current and future electromagnetic environment |
| | Military communications in complex environments |
| | Solutions for cyber operations |
| Defence against asymmetric threats | Advanced land-based IED detection systems |
| | Counter RPAS systems |
| | CBRN threat control |
| Harnessing the civilian technology push | AI – Automatic and intelligent analysis of large volumes of sensor data |
| | AI – Technologies for predictive maintenance of military platforms |
| | AI – Intelligent analysis of multiple sources of information for decision support |
| | Robotics – Unmanned land platforms for defence missions |
| | Robotics – Unmanned surface and underwater vehicles for defence missions |
| | Robotics – Innovative applications of RPAS in defence |
| | Materials – Passive platform and soldier protection |
| | Materials – Reduction of platform and soldier signatures |
| | Space – Use of small satellites and pseudo-satellites in defence applications |
| Enhancement of human capabilities | Technologies for the dismounted soldier |
| | Exoskeletons for defence applications |
| | Advanced training through simulation |
| Energy sustainability | Power generation and energy efficiency in isolated bases and infrastructures |
| | New propulsion systems for manned and unmanned platforms |
| Digital transformation | 4.0 technologies for the Department's digital transformation |
| Initial technological capability development | Technologies for the development of high-power laser weapons |
| | Technologies for RF directed-energy weapons |
| | Energy systems for defence applications requiring high electric power pulses |
| | Detection technologies for the development of active protection systems |

Table 1. Technological objectives focused on the main technological challenges and issues for defence.

**C. Monitoring of emerging technologies with future defence applications**

This last level includes a single objective aimed at conducting a technology watch on progress in emerging technologies at a low technology readiness level, the future development of which could open up new possibilities for defence RDI or have important implications, or even have disruptive effects in the context of defence and security.

As the technology readiness levels are low, still in the field of basic research, no specific investments are planned *a priori*, except in particular cases, although the Ministry of Defence hopes to act as a link between the national research community and any opportunities that may arise in the international defence organisations in which Spain participates, as well as to provide support and guidance to understand their possibilities for application in defence.

## Technological objectives pillar actions

| ACTIONS | |
|---|---|
| [TECO - 1] | Promote the development of RDI activities and projects aimed at achieving the technological objectives defined in the Strategy. |
| [TECO - 2] | Regularly update the technological objectives and the RDI lines of interest to the Ministry of Defence, based on any changes that may occur in operational needs, OCM and OFLP reviews, and the TIB push and technological capabilities. |

Table 2. Technological objectives pillar actions.

# Cooperation pillar

Many factors make it unfeasible to think of a Strategy based solely on actions directed, promoted, managed and funded by the Ministry of Defence to achieve the technological objectives that this Department has set itself during its period of validity. Therefore, cooperation in both its forms – national and international – is a fundamental pillar that will underpin the RDI activities needed to achieve these technological objectives.

## National cooperation

The Ministry of Defence wishes to promote increasing levels of national cooperation in RDI with the other organisations in the Spanish Science, Technology and Innovation System in order to support the technological capability development of the entities in the national technological fabric, so that in the future they can supply the solutions needed by the Armed Forces.

The Department's vision of this national technological cooperation is summarised in Figure 8, in which it is assumed that funding for the development of technologies at low TRLs, open to all possibilities of civilian or military application, will fall to the instruments that exist in the State Plan for Scientific and Technical Research of greater scientific content, while the Ministry of Defence is an observer interested in ascertaining as soon as possible any future repercussions they may have for the defence field.

Once higher levels of readiness are reached, in which specific applications become increasingly relevant, the model once again envisages that the funding of the instruments of the State Plan for Scientific and Technical Research will be able to cover those developments of greater dual content. For its part, the Department's investments will be aimed at adapting technology developed in civilian applications to meet specific defence requirements, with instruments such as the COINCIDENTE programme, as well as promoting progress in niches of specifically military application.

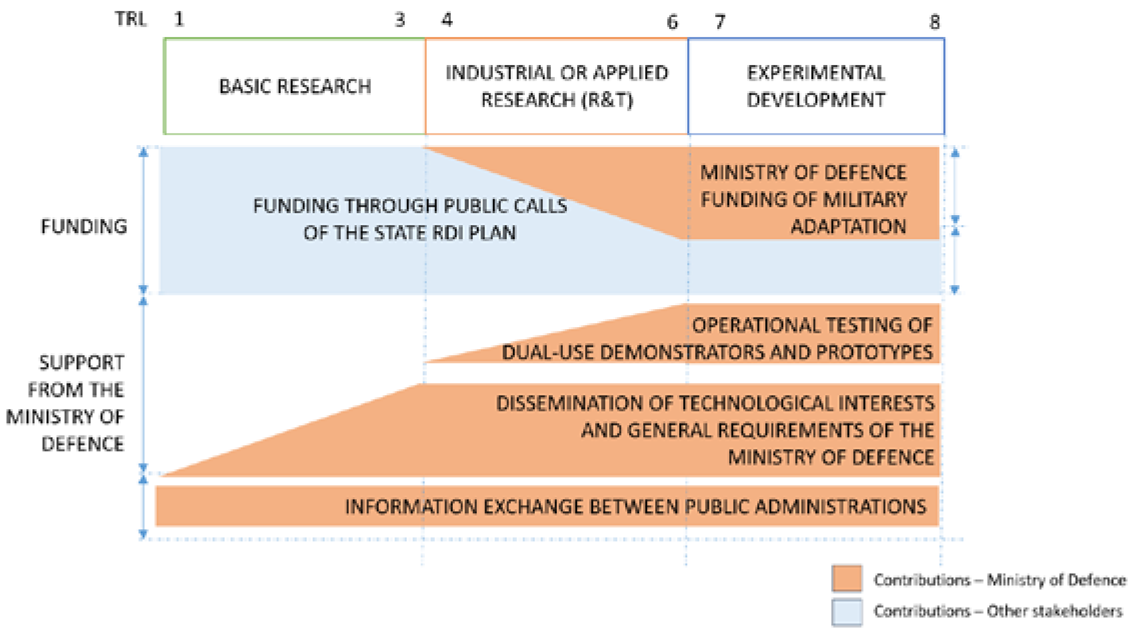


Figure 8. Vision of the Ministry of Defence for national cooperation in RDI.

Apart from the necessary financial resources, the Ministry of Defence has specific means that can help all these externally funded projects to progress to higher levels of readiness and ultimately to the market. Specifically, the Armed Forces' knowledge as an end user of the systems and their vision of the technological needs that will be required in the long term, as well as the ability to test technological solutions in conditions close to their operational use, are elements that can add great value to all these technological developments funded from outside the Ministry. The Department is therefore keen to encourage this type of support for projects, achieving benefits for all parties.

The same applies to cooperation with the Autonomous Communities, through contacts with their regional departments responsible for RDI. In recent years, the Autonomous Communities have been going into more depth in their smart specialisation policies, covering technological areas of a highly dual nature in many cases, which again favours collaborative schemes that make it possible to align actions of common interest.

## International cooperation

International cooperation is considered a key tool for promoting the development of many RDI lines of interest to the Ministry of Defence, as it not only allows it to join efforts and obtain results that would be beyond the reach of countries working alone, but also has the potential to generate greater efficiency by avoiding duplication. To this end, there are various forums and areas of cooperation, governed by specific regulations, legislation and funding conditions, which make it possible to adapt the objectives pursued in the most effective way for the Ministry.

In this regard, it is considered appropriate to continue participating in the traditional forums for international cooperation in defence research, the EDA and the STO, and also in other specific international agreements established bilaterally or multilaterally with other countries for the development of specific projects (similar to, for example, the NGWS).

In addition to participation in the STO, also within the NATO environment, consideration should be given to the possibilities offered by other NATO tools and initiatives, such as the Science for Peace and Security programme which, as a tool in the context of relations with non-NATO allies (partnerships), also offers technological research opportunities and funds projects developed by at least one ally and one partner country of the Alliance, as well as workshops, activities and research courses. Consideration should also be given to the opportunities offered by tools and initiatives that can be created within NATO's existing lines of work on emerging and disruptive technologies. In addition, it is necessary to participate decisively and as intensely as possible in the European Defence Fund (EDF) that the European Commission is going to launch from 2021 to 2027, including both the research (up to TRL 6) and development (TRL 7-8) dimensions, the characteristics and differences of which in terms of the technology readiness levels they pursue, and in terms of how they are funded, require different strategies. In any case, it is essential to make the most of the opportunities that this initiative will offer, and to this end it is vital to ensure that the Department's priorities for cooperation in this framework are translated into the work programmes of the two dimensions.

In the research part of the EDF, which is funded 100% by the European Commission, projects are selected on a competitive basis; therefore, in order to succeed, the participating entities must have sufficient technological capabilities. In certain cases, prior capability development through national programmes could be combined with subsequent participation in EDF consortia through appropriate planning.

Projects channelled through the EDF development section will obtain part of their funding from the European Commission, but will also require the Ministries of Defence of the participating entities to contribute part of their cost, and to express a certain willingness to jointly acquire the developments in the future, should they prove satisfactory. In other words, participation in these projects by the TIB will require the prior agreement of the Ministry of Defence and its commitment to co-funding. Therefore, it will be advisable to channel through this EDF window those large technological development projects of great interest to the Armed Forces that, due to their cost or complexity, cannot be tackled nationally.

On the other hand, and also within the framework of the European Commission, efforts should be made to participate in the areas of the Horizon Europe framework programme and other civilian programmes that involve the development of dual technologies of interest to the Ministry (especially in the field of security), through appropriate coordination with the other national entities involved.

In summary, the following objectives are established to promote the development of each RDI line according to its particularities:

1. Maintain participation in the EDA's R&T activities, especially where defining research priorities and agendas is concerned, and address participation in cooperation projects within this framework when they effectively complement the R&T activities developed nationally or in the EDF forum.

2. Increase national participation in NATO STO activities that are in accordance with the technological lines of this Strategy, and improve the use of their results, explore and harness the possibilities offered by other NATO-promoted research and practical technological cooperation tools in areas other than STO activities, such as partnerships, cooperative security and emerging security risks.

3. Participate appropriately in the development of EDF work programmes, making proposals relevant to European collaboration in defence research and development.

4. Support in the EDF research window those lines of research up to TRL 6 that are in accordance with this Strategy (including support for ongoing multilateral programmes) and in which there is sufficient technological capability to allow adequate participation by the Spanish TIB.

5. Support in the EDF development window the launch of priority technological developments (above TRL 6) of high cost and complexity, including support to ongoing multilateral programmes, or programmes that promote the standardisation and interoperability of systems at European level.

The following chart shows the proposed outline with several examples:

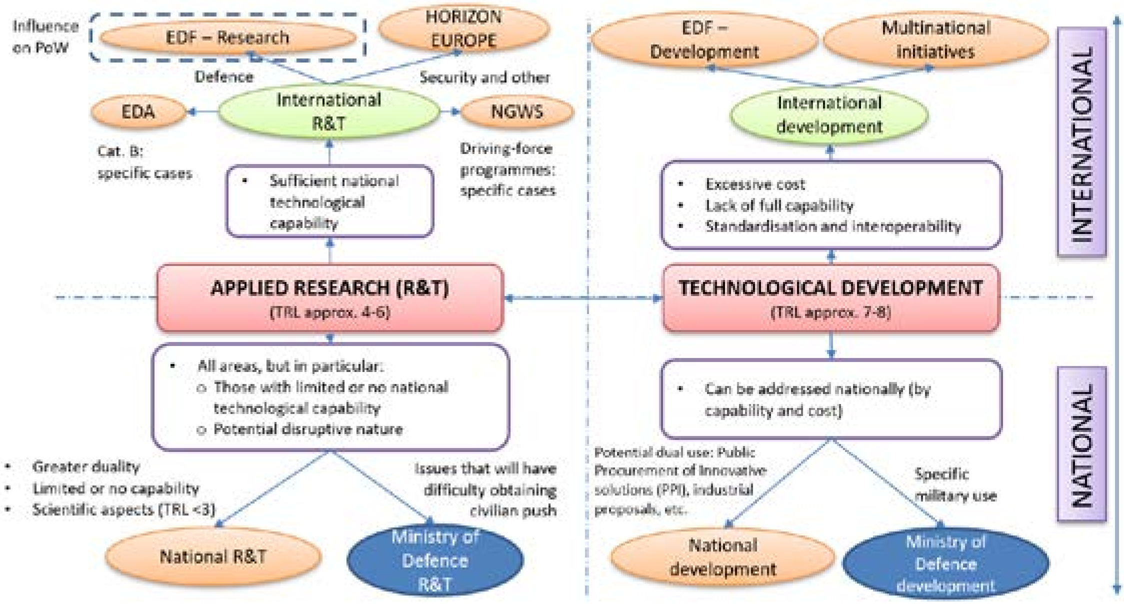


Figure 9. General outline with alternatives for national and international cooperation.

### Cooperation pillar actions

| ACTIONS | |
|---|---|
| [COOP - 1] | Promote joint actions within the scope of the General Action Protocol between the Ministry of Defence, the Ministry of Science and Innovation and their funding agencies, to benefit the capabilities of the national technological fabric in the field of defence. |
| [COOP - 2] | Increase collaboration with all of the Autonomous Community bodies responsible for the technological and industrial development of their regions, taking advantage of the convergence between their smart specialisation strategies and defence interests. |
| [COOP - 3] | Actively participate in the definition of initiatives promoted by the EU for the development of technologies for defence and security applications, especially in the European Defence Fund, promoting the TIB's participation in the opportunities offered by these initiatives. |
| [COOP - 4] | Make better use of the opportunities offered by the EDA and the STO as the main international defence R&T organisations for collaboration in scientific and technological research. |

Table 3. Cooperation pillar actions.

## Continuous improvement pillar

As we have seen in the situation analysis, the Ministry of Defence plays its part in the development of defence RDI through different roles, depending on the organisation and structure involved in the actions. It is therefore essential to establish initiatives aimed at improving the internal organisation and its processes, favouring coordination between its bodies to ensure that the Ministry is a highly efficient catalyst for defence RDI.

Another area to consider concerns instruments, i.e., the tools managed by the Ministry or by other national and international organisations that help to achieve the objectives of defence RDI policy. Together with funding, these instruments are the levers that translate the general guidelines and objectives of the Strategy into concrete and implementable actions, the effects of which can be measured, and their improvement is therefore an objective to be pursued in the Strategy.

### Internal organisation

Order DEF/685/2012, of 28 March, which regulates and coordinates the research and development of weapon systems and equipment of interest to national defence within the Ministry of Defence, is the basis on which to carry out this regulatory development that reinforces the participation of each organisation of the Department's structure in achieving the technological objectives established in this Strategy, overcoming the obstacles that have been identified as preventing the Ministry of Defence from fostering inclusive talent and from being the driving force behind all defence RDI initiatives.

It is also important to reinforce the contribution made in the procurement process, as set out in Instruction 67/2011, of 15 September, of the Secretary of State for Defence, which regulates the procurement process for material resources, when determining the procurement alternative, at which point aspects of RDI policy are assessed to incorporate them into the most appropriate procurement alternative for each need.

The proposed procurement alternatives must:

— Incorporate the results of RDI projects funded or supported by the Ministry of Defence.

— Contribute to the development of industrial capabilities and areas of knowledge of interest to defence, as indicated in Resolution 420/38100/2015, of 30 July, of the Technical General Secretariat, publishing the Agreement of the Council of Ministers of 29 May 2015, which determines the industrial capabilities and areas of knowledge that affect the essential interests of national defence and security.

## Instruments

The ETID groups the instruments for the development of RDI policy into three categories:

1. **Instruments linked to the development of technological solutions.** The objective of such instruments is to promote or support the development of new technological solutions with defence applications by the national technological fabric, which is why they are usually associated with a certain level of public funding. Instruments aimed at the different technology readiness levels (basic research, applied research and experimental development) can be managed by the Department, by other stakeholders of the Spanish Science, Technology and Innovation System, or by other international organisations.

2. **Instruments linked to cooperation in RDI.** The aim of such instruments is the establishment and advancement of new avenues of cooperation in RDI, both nationally and internationally, to expand the TIB's possibilities for developing RDI projects with defence applications.

3. **Instruments linked to technological know-how.** The aim of such instruments is to ensure that information flows within the Spanish Science, Technology and Innovation System. On the one hand, they must ensure that the TIB avails of the information related to technologies of interest to defence and the operational needs that motivate them; on the other hand, they must ensure that the Ministry of Defence is aware of advances in technology with defence applications, as well as the capabilities of the national technological fabric with defence applications, including the projects it develops and the results it obtains.

Although these are three categories of instruments that pursue different goals, to a greater or lesser extent they are all interconnected and are often used in coordination.

Some of the challenges and obstacles to the development of technology with defence applications can be addressed through the improvement or combination of existing instruments, or the creation of new ones. In doing so, the goal is for them to contribute the following characteristics to defence RDI, as described below.

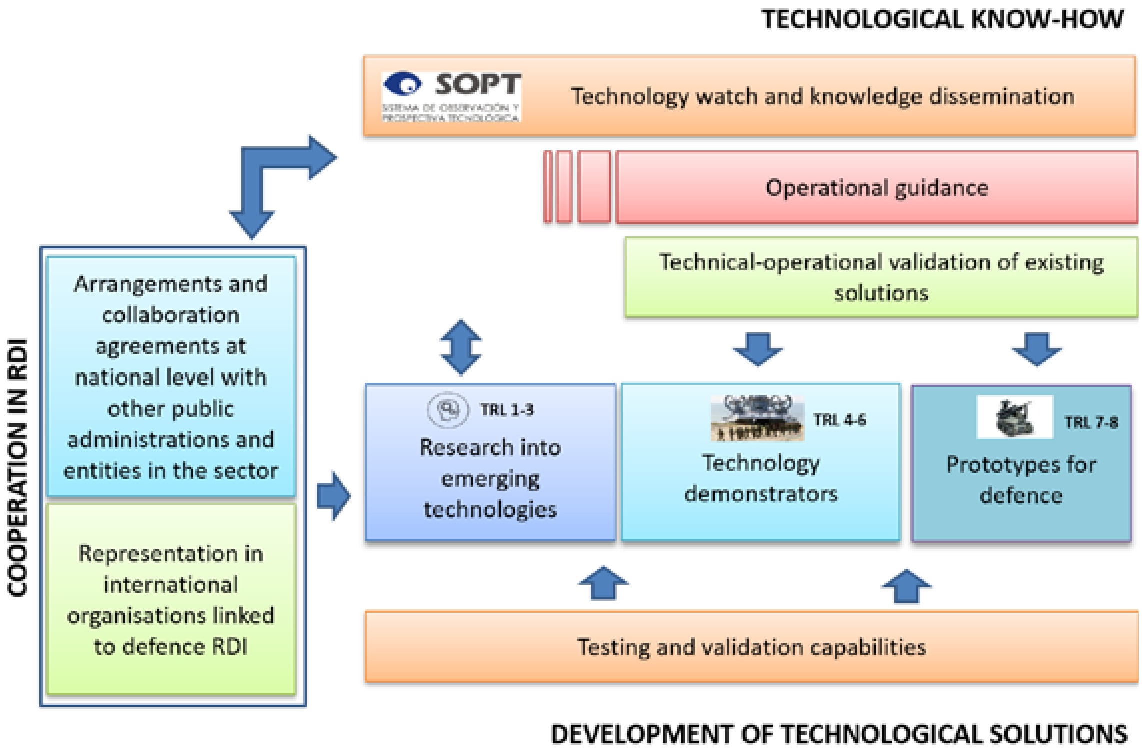


Figure 10. Map of instruments.

***Flexibility***

The aim is to provide options for tackling RDI projects that are suited to the different rates of technological progress, favouring the specific needs of certain technological niches or addressing projects aimed at the innovative use of technology, so that they have the agility that is increasingly in demand.

In this context, the Ministry of Defence manages the COINCIDENTE programme, which has extensive experience as a vehicle for the TIB to take on technological challenges with defence applications. In recent years, this instrument has been adapted to gear it towards specific topics of interest to defence, as well as to launch calls annually, thereby enabling it to be the basis for developing specific calls that are better adapted to these flexibility requirements, using open approaches.

Likewise, in this same period, programmes[3] have been launched based on promoting technical-operational experimentation campaigns, enabling the actual performance of technological demonstrators and prototypes to be tested in conditions that provide an understanding of their proximity to or validity for defence needs. This is particularly interesting for technological solutions with sufficient readiness designed for use in civilian applications, but which have not yet been used in defence, as well as for those cases in which there is a wide variety of alternative technological solutions in the market. The Ministry funds the campaign and prepares a report with the results, proposing the improvements needed to better adapt the systems to the Armed Forces' requirements. This is a knowledge-generating instrument, around which it is possible to orchestrate other initiatives aimed at developing technology that will enable these solutions to enter the defence market more quickly.

[3] Initiatives such as RAPAZ, CONDOR and BARRACUDA, aimed at the technical-operational validation of RPAS, C-UAS and unmanned underwater vehicles, respectively.

### *Complementarity*

The aim is to ensure that the existing instruments of the Ministry of Defence and those of the national cooperation landscape complement one other, to avoid duplication of efforts and increase efficiency by combining actions.

At national level, it is planned to focus on providing support for dual projects funded in PEICTI calls for proposals or developed with private funding, to increase their chances of continuing to adapt to defence, in line with the approaches described in the section on national cooperation.

Thus, in the field of research into emerging technologies (TRL 1-3), there is an interest in achieving this complementarity with certain instruments managed by the AEI regarding certain emerging technologies whose future development could open up new possibilities for defence RDI and even cause disruptive effects, as explained in the "Emerging technologies with potential future defence applications" technological objective.

At higher technology readiness levels, there are a variety of instruments aimed at developing technology demonstrators (TRL 4-6) or prototypes (TRL 7-8), managed by different State and regional bodies, which are also conducive to achieving this complementarity. The instruments of the PEICTI 2021-2023 included in the programme to develop, attract and retain talent, the programme to promote RDI and its transfer, the programme to catalyse innovation and business leadership and the programme to tackle the priorities of our environment, offer very interesting possibilities for the projects presented by the TIB, aligned with the technological objectives and RDI lines of this Strategy of a more dual nature, to be developed.

In the case of some of these instruments, this could represent an alternative means of funding so that project proposals submitted to calls such as COINCIDENTE which, having been positively evaluated, have not attained the available funding, may have a chance of progressing.

On the one hand, this means working with the organisations responsible for managing these instruments[4] to design stable and continuous collaboration mechanisms that favour this complementarity, adapted to the bottom-up and competitive approach that characterises such instruments. On the other hand, the Department must adapt and systematise its support so that its capabilities of technical-operational validation and defence-orientation of the projects can be provided in an effective and efficient manner.

In particular, in relation to this operational guidance to support the suitability of projects for defence purposes, it is expected that sufficiently detailed requirements of use to the TIB stakeholders will be developed, while safeguarding the necessary security requirements. Placing special emphasis on dissemination initiatives (e.g., technical workshops) aimed at explaining the technological needs of the Armed Forces to the TIB is also envisaged.

[4] Within the framework of the General Action Protocol between the Ministry of Defence, the Ministry of Science and Innovation and their funding agencies, as well as agreements that could be entered into with other entities at regional level.

In relation to operational-technical validation, it is expected to make use of the currently existing capabilities, as well as to promote the development of new testing and validation capabilities through INTA (National Institute of Aerospace Technology), in those specific niches of interest to defence that are not available in other technological centres of the Spanish Science, Technology and Innovation System or should this prove insufficient to address the established technological objectives.

### *Usefulness*

The aim is to ensure that the opportunities that enable the development of technology with defence applications are known and used by a growing number of entities in the national technological fabric.

To this end, it is planned to strengthen the Ministry's instruments responsible for collecting, managing and using technological knowledge of interest to defence to carry out the various functions of the organisation, as well as those relating to the dissemination of this knowledge to all interested parties, to foster progress and align actions.

Specifically, it is planned to reinforce the functioning of the Technology Watch and Foresight System[5] to encourage the involvement of a greater number of national entities in defence issues, as well as to improve the functioning of the Department's means of disseminating technological information (Defence Technology and Innovation Portal, Defence Technology Watch Bulletin, National Congress on R&D in Defence and Security (DESEi+d), etc.) on technological advances, existing capabilities, technological needs and opportunities for collaboration in RDI nationally and internationally, so that they can provide effective support to the orientation of the TIB, complementing other dissemination initiatives outside the Department.

## Funding

The financial framework within which this Strategy will operate is defined in the Financial Resource Planning Scenario Forecasts used as the starting document in the definition phase of the Defence planning cycle.

These financial scenarios have been updated in line with the successive economic programmes carried out at the date of preparing of this document.

Spending policy 46 (R&D) in the defence sector (464) includes spending programmes 464A (Research and studies of the Armed Forces), which is managed by the Ministry of Defence, as well as programme 464B (Support for technological innovation in the defence sector), which is managed by the Ministry of Industry, Trade and Tourism. Funding for this policy, in the latest approved budget[6] and in the part allocated to investments, amounted to around 550 million euros.

[5] An instrument aimed at technological assessment, evaluation, monitoring and dissemination, regulated by Instruction number 01/2018, of 27 February, of the General Director of Armament and Materiel. For more information: http://www.tecnologiaeinnovacion.defensa.gob.es/es-es/Presentacion/Paginas/ SOPT.aspx

[6] At the date of preparing this document, the latest approved budget is for 2018.

However, the part of the policy assigned to programme 464B[7] varies according to the major programmes currently being pre-funded by the Ministry of Industry, Trade and Tourism and will depend at all times on major developments underway.

Given the economic situation caused by the COVID-19 health crisis, it is difficult to predict which driving-force programmes will be approved by the government during the period in which this Strategy is in force and which will be developed on the basis of the specific industrial and technological plans (PLANITEC) drawn up for each case.

However, there is no doubt that the need to boost and recover the national TIB will make it essential to design measures that contribute to recovering the pre-crisis industrial, technological and employment potential as soon as possible. To this end, it should be borne in mind that the defence industry is a strategic and fundamental sector in mitigating the social impact of the pandemic, recovering highly qualified jobs and work teams that develop high added value technologies and also promoting RDI as a crucial element to face the challenges and threats of the future and make our TIB competitive. This will help meet the objective of developing advanced technologies for incorporation in future major platforms and weapon systems.

For the objectives framed within the development of technologies for the main defence technological challenges and issues, this Strategy can count on the funding allocated to the 464A budget programme, as well as on the multiplier effect that these investments may have, as they are supported by the cooperation pillar and, therefore, can mobilise resources from the Spanish Science, Technology and Innovation System and funding from the European Union and other international organisations in multinational collaboration mechanisms.

As one of the guidelines of this Strategy is to orient RDI activities towards the technological objectives set out therein, in some instances it may be possible to fund RDI lines of interest to defence that have not been considered technological objectives.

The aim of this Strategy is therefore to allocate eighty per cent of the available financial resources to the development of technological objectives, leaving twenty per cent for the other RDI lines of interest to defence included in Appendix A.

All RDI activities with defence applications funded by the 464A budget programme will be included in a Strategic Defence Action within the PEICTI 2021-2023, which may also include other programme actions managed by units outside the Department whose goals are in line with this

[7] The 464B expenditure programme (Support for technological innovation in the defence sector), managed by the Ministry of Industry, Trade and Tourism, grants repayable loans to the sector's industry.

The immediate objective of this programme is to support the participation of Spanish companies in the development of defence-related industrial technology projects of a strategic or international nature (normally associated with special armament programmes (PEAs)).

The industrial technology projects eventually have an impact on the budget of the Ministry of Defence through expenditure programme 122B (Special Modernisation Programmes), at which point the sector's industry begins to repay the loans to the Ministry of Industry, Trade and Tourism.

Consequently, for the purposes of defence RDI funding, it can be considered that the Ministry of Defence will end up assuming the cost of these technological projects through the 122B expenditure programme.

Strategy and with the 464B budget programme for those technological objectives included in the area of developing advanced technologies for their incorporation into future major platforms and weapon systems.

## Monitoring

Undoubtedly, a Strategy with a six-year timeframe, which sets guidelines and objectives in the technological field, may be questioned soon after its promulgation if the mechanisms are not in place to enable its review.

Therefore, a fundamental element for the continuous improvement of the RDI processes developed in the Department is the annual review of the Strategy.

This review will be carried out by the R&D Advisory and Coordination Board, regulated by Order DEF/685/2012, of 28 March, and will be based on complementary analyses as follows:

Firstly, a monitoring report, which will be prepared on an ongoing basis, based on the indicators designed and included in this document, the objective of which is to measure the progress achieved in the implementation of the Strategy.

Secondly, an analysis of the suitability of the technological objectives set out in the Strategy with regard to the current context, based on the information compiled by the technology watch and foresight function, assessing the progress and changes taking place in the following three areas that have determined their selection:

— Evolution of threats and scenarios and, therefore, of military capabilities, as a consequence of the reviews of the Defence planning cycle, provided for in Ministerial Order 60/2015, of 3 December. To carry out this task, the Military capability objective monitoring report, which is issued annually, will be taken into account.
— Changes in technological analyses and reports, and results from monitoring emerging and disruptive technologies.
— Progress in the development of technological capabilities by the national TIB.

Thirdly, an assessment of the suitability of the guidelines and actions included in the Strategy, depending on the international context and any changes that may occur in the Spanish Science, Technology and Innovation System.

Fourthly, any other aspect that may make it advisable to introduce changes in the Strategy.

### *Indicators*

To facilitate the monitoring of the implementation of this Strategy, a measurement model has been designed that seeks to achieve a compromise between the need to measure progress and the reality of availing of reliable data that can support these measurements and the evaluations obtained from them.

This model combines two dimensions: actions promoted during the Strategy's period of validity and results obtained from RDI projects.

### a. Actions promoted during the Strategy's period of validity

The Strategy envisages RDI investments by the Ministry of Defence, as well as actions in the collaboration and continuous improvement pillars, which are not an end in themselves, but rather a means to promote advances in technological objectives and RDI lines of interest to defence.

All these actions are expected to promote the carrying out of RDI projects with defence applications in which the TIB will participate. Although launching projects in a given technological field does not in itself ensure the achievement of quality advances, it is a first indicator of whether the efforts being made with the Strategy are going in the right direction and whether the volume of projects initiated is significant in magnitude.

*National investments made*

Quantitative indicators on the overall effort made are contemplated:

- *Public investment in RDI for defence purposes (464A, 464B).* Aimed at ascertaining the effort made by the General State Budget (PGE), specifically in the case of RDI for defence purposes.
- *Number of projects and economic volume mobilised in dual projects funded by State and regional bodies, associated with actions in the national cooperation pillar.* This is an approximate measure, as it is highly conditioned by the knowledge of these projects and how applicable they are to defence, although it is an indicator of the progress made in the field of national cooperation.
- *Number of externally funded projects in which the Ministry of Defence provides non-financial support.* The aim is to measure the size and level of effectiveness of the indirect support model proposed in the national cooperation section of this Strategy.

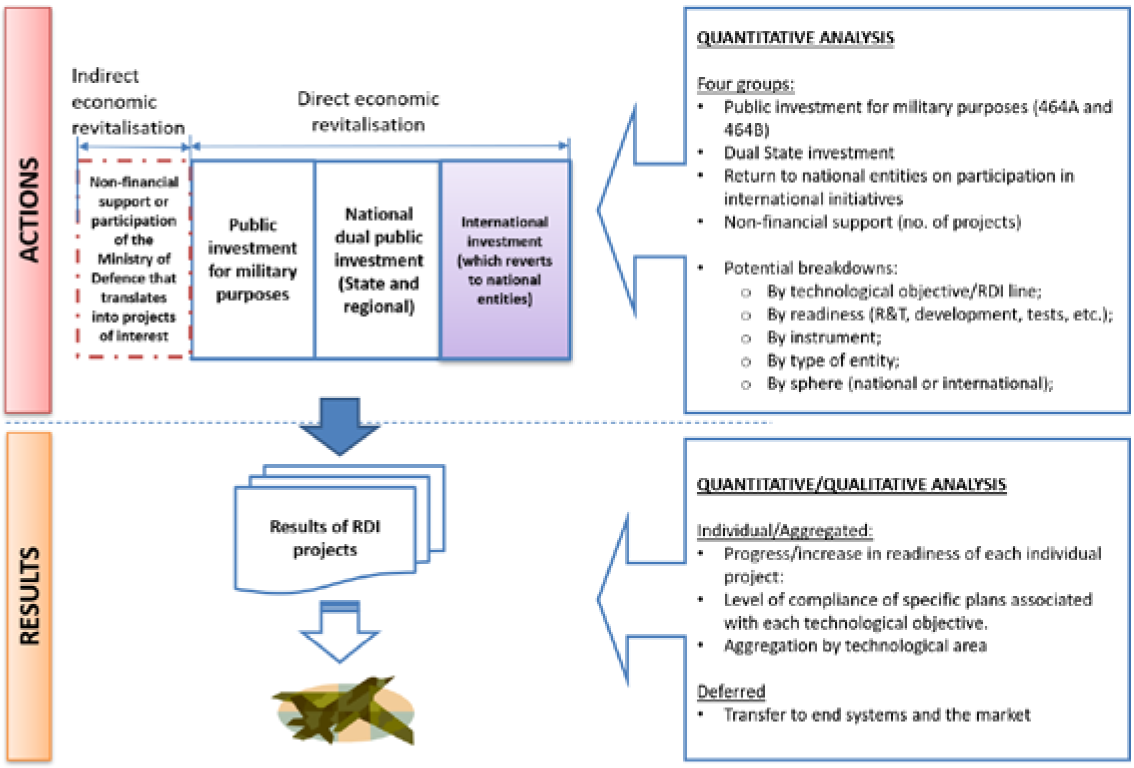


Figure 11. Measuring progress in defence RDI.

From the individual projects, it is expected that other particular indicators will be obtained according to the following perspectives:

- Depending on their contribution to technological objectives and RDI lines.
- Depending on the technology readiness levels of the projects: R&T, development and technical-operational testing or other defence RDI enabling activities.
- Depending on whether they are carried out in a national or international context.
- Depending on the type of leading entity.
- Depending on the instrument or call.

*Investments made at international level*

Quantitative indicators related to the level of TIB participation in the different EDF sections, as well as in Horizon Europe, NATO and other multinational initiatives are considered as follows:

- % return in the EDF research section and number of projects selected out of the total.
- Investments in the EDF development section in relation to the economic volume mobilised.
- Investments in other multinational technology development initiatives in relation to the economic volume mobilised.
- Number of approved Horizon Europe projects with Ministry of Defence participation.
- Number of STO initiatives with participation of national representatives in their organisation compared to the total.
- From the individual projects, it is expected that particular indicators will be obtained according to the following perspectives:
- Depending on the area (European Commission, NATO, multinational, etc.), initiative, call or panel (in the case of STO).
- Depending on contribution to technological objectives and RDI lines.

### b. Results obtained from RDI activities

To measure the relevance of the results obtained from the RDI activities, two timeframes are considered.

Firstly, at the end of each RDI project, by estimating the progress achieved in the project (e.g., in terms of TRL) by means of qualitative indicators, which will be aggregated to periodically provide measures of progress according to RDI lines and technological objectives and, in particular, as foreseen in the specific plans associated with each of these objectives. This type of measurement is envisaged both for projects funded by the Ministry of Defence and for external projects.

Secondly, a longer timeframe to identify the extent to which the efforts made with the Strategy translate into technological advances incorporated into end systems that reach the market and can be used by the Armed Forces. In this case, as these measures are deferred over time, it is difficult to carry them out in a six-year timeframe. However, during the period of validity of the ETID, it is planned to further develop the design and measurement of this type of indicators to be able to assess the effectiveness of RDI activities in future strategies.

## Continuous improvement pillar actions

| INITIATIVES | |
|---|---|
| [CONI - 1] | Improve the flow of information within the Ministry of Defence as well as the processes relating to the planning, procurement, management and leverage of the results of RDI activities, to ensure useful, effective and efficient funding. |
| [CONI - 2] | Improve coordination between the different Department bodies that are associated with RDI. |
| [CONI - 3] | Work towards having transparent and appropriate instruments for each technology readiness level, which favour the participation of all types of entities from the national technological fabric and complement other instruments of the State Plan for Scientific and Technical Research. |
| [CONI - 4] | Ensure that the organisation has sufficient capacity to promote national cooperation with other State and regional bodies that fund civilian and dual RDI. |
| [CONI - 5] | Comprehensively measure RDI investments and progress made in each technological field to support decision-making. |
| [CONI - 6] | Foster, in the process of acquiring material resources, procurement alternatives that incorporate the results of RDI projects promoted by the Ministry of Defence and enhance the development of the technological objectives and RDI lines of interest defined in the Strategy. |

Table 4. Continuous improvement pillar actions.

# APPENDIX A. RDI lines of interest to defence

The RDI lines of interest to defence included in this Strategy are organised into the 11 **areas**[1] set out below:

1. Weapons and ammunition
2. Sensors and electronic systems
3. Common technologies for bases and installations, platforms and soldiers
4. Bases and installations
5. Land platforms
6. Naval platforms
7. Air platforms
8. Space systems
9. Soldier
10. CBRNe
11. Information, communication and simulation technologies

The first group of areas represents development fields of technologies and systems typically used in defence, which may be separate entities within defence needs or integrated into larger platforms and weapon systems. Thus, both areas 1 (Weapons and ammunition) and 2 (Sensors and electronic systems) represent areas in which the nature of the systems developed or the high performance required for their use in defence applications give rise to a significant number of RDI lines. This is also the case of area 11 (Information, communication and simulation technologies), which cuts across the other areas and groups together the RDI lines related to C4I systems, cyber defence and simulators, all of which are widely used in defence.

On the other hand, areas 4 to 9 (Bases and installations, Land platforms, Naval platforms, Air platforms, Space systems and Soldier) represent the main application fields of the technologies developed in the Strategy. In these areas major platforms and weapon systems used in defence are often developed, the latter frequently adapting and integrating technological developments addressed in other areas of the Strategy according to their specificities and the requirements of the environments in which they operate. These areas are complemented by area 3 (Common technologies for bases and installations, platforms and soldiers), which includes RDI lines equally applicable to most of the aforementioned areas, thus avoiding duplication of interest in each of them. Area 9 (Soldier) can be considered a particular case, as it groups together human-centred developments and innovations which are transferred through their equipment or their cognitive abilities and health condition.

[1] This structure has evolved from that of the ETID 2015. Therefore, areas 3 to 8, which in the previous version of the Strategy were part of the same area, have come to be considered separately, given their special relevance.

Finally, area 10 (CBRNe), which focuses on the development of defence technologies to counter asymmetric threats, is a particular case, due to its greater orientation towards **defence-specific threats.**

Each of these areas, in turn, is structured into **sub-areas**[2] grouping together the RDI lines that address related technological challenges (see Figure 12).

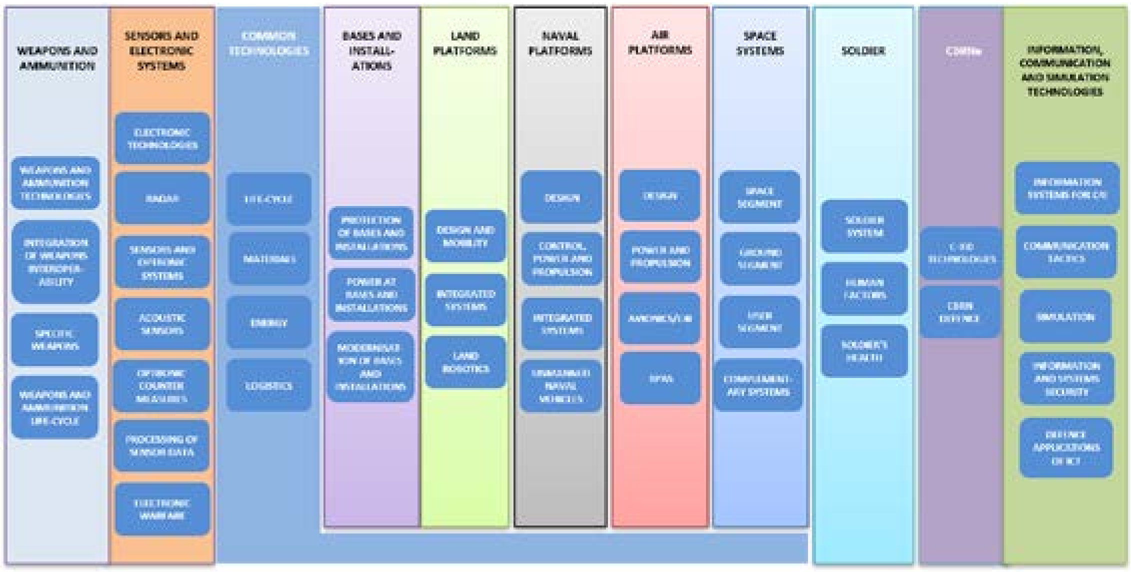


Figure 12. ETID areas and sub-areas

Although the organisation of information is hierarchical, there are multiple horizontal relationships between these sub-areas and their RDI lines, a consequence of the complexity inherent in the use of technology in the multiple types of defence systems and applications.

Each of the RDI lines of interest to defence is set out below, highlighting those that contribute most to achieving the ETID's technological objectives. The complete list of these RDI lines is included in Table 5.

Finally, Table 6 shows the relationship between each of the sub-areas of the ETID and the areas of knowledge that affect the essential interests of defence and security (according to Resolution 420/38100/2015, of 30 July, of the Technical General Secretariat, publishing the Agreement of the Council of Ministers of 29 May 2015). Table 7 also includes an indicative relationship between the strategic RDI lines included in the EECTI 2021-2027 and the RDI lines of the ETID.

[2] In the ETID 2015, technological information was collected through technological goals, which were organised into areas and functional lines of action. To avoid terminological confusion, in this version they are organised into areas and sub-areas, which include RDI lines of interest to defence.

| 1. WEAPONS AND AMMUNITION | |
|---|---|
| **1.1. WEAPONS AND AMMUNITION TECHNOLOGIES** | |
| **1.1.1. Improved performance of ammunition through effects and activation technologies** | Research and development of technologies applicable to ammunition charges, including both the charge and its conventional physical effects (terminal ballistics, energetic materials to form explosives and pyrotechnics, shaped charges, fragmentation charges, etc.), or non-conventional ones (EM effect charges, acoustic effect charges, etc.), as well as effect activation and control systems (fuses, control devices, actuators, etc.), seeking to improve performance, efficiency and effectiveness in terms of lethality and scalability. |
| **1.1.2. Improvements in ammunition propulsion technologies** | Research and development of technologies in the field of conventional ballistic propulsion systems through improved propellants (projection charges, solid propellant grains for rocket motors, etc.), internal and external ballistics, as well as conventional self-propulsion technologies (rocket motors, etc.), and new propulsion technologies (electric, electromagnetic, hybrid, among others), to obtain better performance, in particular by increasing the range and speed and reducing thermal effects and heat signature or plume. |
| **1.1.3. Improved safety in the use of weapons and ammunition through control systems, insensitive munitions and other specific measures** | Research and development of technologies to increase safety in the use of munitions through different strategies, which include the reduction of their sensitivity to various stimuli, such as munitions using highly insensitive energetic materials, additional control devices in fuses and activation systems, etc., as well as safety system technologies applicable to weapons and ammunition in general, which may incorporate specific systems and measures. |
| **1.1.4. Improved performance of munitions through guidance and advanced control devices** | Research and development of technologies to develop complex munitions to increase precision through the incorporation of guidance and control capabilities, as well as to increase their autonomy through the incorporation of sensor data processing technologies, artificial intelligence, communication links, etc., achieving operational advantages mainly related to improved engagement effectiveness, reduced logistical load or reduced potential collateral damage.<br><br>This is the core of the «Munitions guidance and advanced control technologies» objective. |

| 1. WEAPONS AND AMMUNITION | |
|---|---|
| **1.2. WEAPONS INTEGRATION AND INTEROPERABILITY TECHNOLOGIES** | |
| **1.2.1. Technologies for improved integration and interoperability of weapons with the soldier system** | Research and development of technologies applicable to the integration of individual weapons with the soldier system that contribute to improving firing efficiency, particular emphasis being placed on the integration of electromechanical control devices that incorporate greater weapon functionality, improved situational awareness and greater interoperability with C2 architectures, etc. These are considered weapons for individual use.<br>This is part of the «Technologies for the dismounted soldier» objective. |
| **1.2.2. Technologies for improved integration and interoperability of weapons with platforms and command and control systems** | Development of technologies to improve integration and increase the level of interoperability of weapons both in manned and remotely manned weapon systems and platforms of all types, and in land-based infrastructures, with a particular focus on the development of architectures for mechanical, electrical, electronic and software integration to increase both compatibility, by simplifying the integration process, and automation, through the integration of remote weapon control systems and processes integrated into command and control systems. |

| 1. WEAPONS AND AMMUNITION | |
|---|---|
| **1.3. APPLICATION AND TECHNOLOGY-SPECIFIC WEAPONS** | |
| **1.3.1. High-power laser directed-energy weapons** | Design, development and integration of high-power laser directed-energy weapon (LDEW) systems for use in military and security applications, providing additional self-defence and response capabilities.<br><br>This is the core of the «Technologies for the development of high-power laser weapons» objective. |
| **1.3.2. RF directed-energy weapons** | Development of radio frequency (RF) directed-energy weapon technologies, with the aim of being able to address in the future the development of electronic attack systems that are capable of generating a high enough level of RF power to temporarily disable or even destroy electronic systems of the threat.<br><br>This is the core of the «Technologies for RF directed-energy weapons» objective. |

| 1. WEAPONS AND AMMUNITION | |
|---|---|
| **1.4. LIFE-CYCLE SUPPORT TECHNOLOGIES FOR WEAPONS AND AMMUNITION** | |
| **1.4.1. Management and control of ammunition life cycle through support tools** | Development of technologies enabling improved monitoring and control of the climatic and physicochemical conditions of ammunition during its life-cycle, to optimise its useful life and reduce the logistical load. |
| **1.4.2. Improvement of efficiency and reduction of effects on health and the environment in the production, demilitarisation, transport and storage of weapons and ammunition** | Research and development of technologies to improve the efficiency and/or reduce the potential effects on human health and the environment of the processes related to the life-cycle of ammunition, based on the use of new technologies, new materials or the implementation of new production, demilitarisation, transport or storage processes and techniques. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.1. ELECTRONIC TECHNOLOGIES** | |
| **2.1.1. High-performance RF devices, modules and antennas** | Improvement of the performance of devices and components that are part of military radio frequency (RF) systems by using technologies and developments applicable to these elements to achieve advanced functionalities in radar, electronic warfare (EW) and communications systems.<br><br>This is part of the «High-performance electronic technologies» objective. |
| **2.1.2. Application of photonics technology to RF systems** | Application of photonics technology to improve the performance of military radio frequency (RF) systems through developments at component, subsystem and system level, providing significant benefits in terms of reduced size, weight and power (SWaP) of RF systems on board platforms.<br><br>This is part of the «High-performance electronic technologies» objective. |
| **2.1.3. SMRF architecture** | Development of a standardised SMRF (scalable multifunction RF systems) architecture for the implementation of military RF systems that are modular (based on the interconnection of hardware and software blocks) and multifunctional (where standard hardware is used to provide all the RF functionalities required by the platform). The use of this architecture is expected to provide cost benefits in the development and maintenance of military RF systems, and to facilitate the rapid incorporation of new technologies and features into these systems. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.2. RADAR** | |
| **2.2.1. Non-cooperative target identification (NCTI) and automatic target recognition (ATR)** | Development of improved techniques for non-cooperative target identification (NCTI) and algorithms for automatic detection, localisation, recognition and identification of static and moving targets (ATR – automatic target recognition) from radar sensor data. Improvements in these techniques and algorithms have significant potential to reduce collateral damage and fratricide during operations. |
| **2.2.2. Novel radar algorithms and architectures** | Research and development of advanced radar signal processing algorithms to provide enhanced detection and tracking of elusive/difficult targets in complex environments (e.g., with a high level of clutter and interference and in adverse weather conditions) and of new radar architectures that may provide significant advantages over existing systems or provide completely new capabilities. |
| **2.2.3. Air defence radar systems** | Development of leading-edge air defence radar systems for both land and naval units, to enhance the acquired national technological capability and to advance in the development of new state-of-the-art systems. |
| **2.2.4. SAR/MTI systems** | Development of HW and SW technologies for SAR/MTI (synthetic aperture radar/moving target indicator) radar systems on board air platforms. SAR imaging technology offers the possibility of «change detection» in a terrain through the application of interferometric SAR (InSAR) techniques, while MTI techniques enable the moving target discrimination capability. SAR imaging can also reveal information that is hidden in other regions of the spectrum (visual, infrared, etc.), enhancing the information obtained from these sensors and increasing the probability of target detection. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.3. SENSORS AND OPTRONIC SYSTEMS** | |
| **2.3.1. EO/IR (electro-optical/infrared) detector-based systems** | Research and development of new optronic systems based on detectors in the visible (EO) and infrared (IR) range with improved performance compared to existing systems for use in all types of ISTAR military missions. In particular, emphasis is placed on the development of systems based on SWIR detectors (1-3μm), hyperspectral and multispectral systems using filters or multi-band detectors, as well as sensors involving the fusion of the different IR spectral bands (NIR, SWIR, MWIR, LWIR) with the visible range. Information processing using conventional techniques is included. |
| **2.3.2. Night vision systems (NVS)** | Research and development for the improvement of night vision systems (NVS) based on image intensifier tubes or high sensitivity detectors. Of particular relevance is the digitisation of the signal through the development of new systems based on high sensitivity detectors or the integration of micro-cameras in the systems based on intensifier tubes. The acquisition of connectivity capabilities from the different fusion systems of IR detectors with intensifier tubes-based systems, as well as SWaP improvements, are also considered to be of great interest. |
| **2.3.3. Laser-based systems for telemetry, LIDAR, guidance and target designation** | Research and development for the improvement of technological solutions based on laser technologies for use in defence, as well as for the development of new systems. This includes activities in systems for telemetry, target designators, LIDAR (light detection and ranging) imaging and navigation aid systems, laser guidance systems or other innovative applications such as lasers for underwater environments. Information processing using conventional techniques is included. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.4. ACOUSTIC SENSORS** | |
| **2.4.1. Underwater acoustic sensors** | Research and development of new sonar systems with improved performance compared to existing ones for all types of military applications. In particular, the focus is on the development of new multistatic systems, composed of several fixed sonar systems installed and working in cooperation, including the use of networks of multiple high and medium frequency systems on fixed nodes and unmanned platforms to protect installations. In addition, the intention is to develop new automation systems for signal interpretation and new high frequency sonars (around 100 KHz) for customised incorporation on small, unmanned platforms, both surface and underwater. |
| **2.4.2. Atmospheric acoustic sensors** | Research, development and integration of land acoustics systems and signal processing for military applications, in particular for detection of detonations and localisation of fire muzzle flash weapons, as well as for trajectory estimation of air and land moving targets. Information processing using conventional techniques is included. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.5. SENSOR DATA PROCESSING** | |
| **2.5.1. Sensor fusion** | Development of improved algorithms and techniques for the fusion of data from different sources (EO/IR, multispectral and hyperspectral imagery, LIDAR, SAR, ISAR, video in motion, acoustic signatures, LINK-16/22 traces and GMTI data, etc.). |
| **2.5.2. Automatic and intelligent analysis of large volumes of sensor data** | Development of algorithms to analyse data from different sensors used in defence to automatically detect, recognise or identify the presence on the scene of entities of significance and interest to the Armed Forces, thereby reducing the analysis load for human operators.<br>The focus is specifically on the application of the latest advances in artificial intelligence to analyse the data provided by sensors used in highly complex scenarios, where so far there have been no worthwhile alternatives to automate these analyses.<br>This is the core of the «AI – Automatic and intelligent analysis of large volumes of sensor data» objective. |
| **2.5.3. Sensor data processing for the development of active protection systems** | Research and development of technological solutions focused on the detection, identification and tracking of high-speed air threats, to obtain systems with C-RAM (counter rocket, artillery and mortar) capabilities. Projectile detection, identification and tracking is the most critical stage of the process, as it is the enabler for subsequent stages (ballistic calculation and neutralisation), and must be executed with high accuracy and critical response time requirements.<br>This is the core of the «Detection technologies for the development of active protection systems» objective. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.6. OPTRONIC COUNTERMEASURES** | |
| **2.6.1. Active DIRCM protection on air platforms** | Research and development of laser-based DIRCM (directed infrared countermeasures) systems for integration on military aircraft to cope with the launch of infrared guided missiles, present in multiple theatres of operations. In particular, their integration into MWS (missile warning systems) and multispectral decoy launch systems is of interest. |
| **2.6.2. Pyrotechnic decoys, flares, smoke canisters** | Research and development of pyrotechnic systems necessary for the protection of air, naval and land platforms, and in particular of multispectral decoys capable of responding to the threat of infrared guided missiles, as well as stealth systems using smoke screens that prevent the targeting or guidance of small and large calibre ammunition in all infrared bands, including in the visible range. |

| 2. SENSORS AND ELECTRONIC SYSTEMS | |
|---|---|
| **2.7. ELECTRONIC WARFARE** | |
| **2.7.1. Non-communications electronic warfare systems** | Development of state-of-the-art non-communications electronic warfare systems, both electronic support measures (ESM) and electronic countermeasures (ECM), to which technological advances in RF components, modules and antennas, as well as specific advanced algorithms, will be applied.<br>This is part of the «Electronic warfare solutions adapted to the current and future electromagnetic environment» objective. |
| **2.7.2. Communications electronic warfare systems** | Development of cutting-edge ESM/COMINT and ECM communications electronic warfare systems, to which technological advances in RF components, modules and antennas will be applied, using the most advanced warning and signal intelligence features, adapted to the new communications signals present in the electromagnetic (EM) environment.<br>This is part of the "Electronic warfare solutions adapted to the current and future electromagnetic environment" objective. |
| **2.7.3. Multi-platform and cooperative electronic warfare** | Development of technologies enabling the implementation of multi-platform and cooperative electronic warfare systems. The coordinated and cooperative use of electronic warfare equipment on board different platforms will make it possible to improve the accuracy of detection, localisation and identification of the opponent's RF emissions and to increase the effectiveness of electromagnetic countermeasures against the enemy's systems. |
| **2.7.4. Frequency jamming counter RCIED** | Development of leading-edge frequency jamming systems to counter radio-controlled improvised explosive devices (RCIEDs). These are portable personal, vehicular and fixed installation systems, offering versatility and multi-purpose capabilities, which implement the different modes of operation (active, reactive and hybrid) and also enabling accurate time synchronisation means to allow interoperability and compatibility both with allied communications and jamming systems. |

| 3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS | |
|---|---|
| **3.1. LIFE-CYCLE** | |
| **3.1.1. Platform maintenance** | Development of technologies to facilitate the maintenance of military platforms (land, naval and air), to increase their availability and to extend their operational life, both structurally and in terms of the functioning of their equipment and systems, with a view to reducing maintenance tasks and costs. Technologies integrated into the platforms themselves are considered to facilitate their preventive and predictive maintenance, as well as all types of repair processes.<br>This is part of the «AI – Technologies for predictive maintenance of military platforms» objective. |
| **3.1.2. Data intelligence applied to predictive maintenance of platforms** | Development of algorithms based on artificial intelligence for the automatic analysis of large volumes of data obtained from sensorisation and maintenance work on platforms, so that they are capable of accurately and reliably predicting the remaining useful life of each component or system.<br>This is part of the «AI – Technologies for predictive maintenance of military platforms» objective. |
| **3.1.3. Simulation to support platform life-cycle** | Development of innovative technological solutions that, by making use of the latest advances (virtual and augmented reality, digital twin, etc.), provide methods and representations that facilitate the specification, design, development and maintenance of complex platforms or systems of interest to defence. |
| **3.1.4. Protection against corrosion and degradation processes** | Development and incorporation of technologies to protect platforms from corrosion and degradation processes in any kind of aggressive environment, with the aim of reducing their deterioration and that of their subsystems, thus extending their useful life. Any type of aggressive environment will be covered: processes at room temperature, oxidation processes at high temperatures, antifouling, etc. |

| 3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS | |
|---|---|
| **3.2. MATERIALS** | |
| **3.2.1. Platform weight reduction** | Research and development of lightweight materials and structures which, without reducing the performance of the platforms into which they are integrated, make it possible to increase their operational capacity and transportability, while also improving other associated logistic aspects (lower consumption and greater autonomy, mobility, etc.). This reduction in weight must not entail any reduction in the operational capacity, mechanical or passive protection properties of platforms. |
| **3.2.2. Passive platform protection systems** | Research and development of passive protection systems that can replace existing armour on platforms (land, naval and air), reducing their weight and maintaining or improving their capability of protection against ballistic impacts and explosions.<br>This is part of the «Materials – Passive platform and soldier protection» objective. |
| **3.2.3. Platform signature reduction through materials** | Research and development of materials enabling the reduction of the radar, IR, acoustic, visible, etc., signature of platforms (land, naval and air), improving their stealth capability, without impairing other capabilities such as mobility, navigation, etc.<br>This is part of the «Materials – Reduction of platform and soldier signatures» objective. |
| **3.2.4. Materials for high temperature applications** | Research and development of materials for high temperature applications (propulsion systems, structures operating in high temperature conditions, fire resistant elements, etc.), which can be integrated into military systems and which allow control of their performance and behaviour throughout the entire period of use in such temperatures. These are materials for use in temperatures ranging from 100ºC to above 1,000ºC |

| 3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS | |
|---|---|
| **3.3. ENERGY** | |
| **3.3.1. High-power energy systems** | Support to the enhancement of national research capabilities of the technological and industrial base regarding on-board energy systems that can supply the necessary power for new systems requiring high pulses of electric current, either short or sustained in time, such as directed-energy weapons, electromagnetic weapons or active armour. These developments comprise both energy storage systems that enable fast charging and de-charging cycles, as well as the associated power electronics control.<br>This is the core of the «Energy systems for defence applications requiring high electric power pulses» objective. |
| **3.3.2. Energy harvesting systems** | Adaptation and validation of technologies for the microgeneration of electric power through small-scale systems based on ambient energy harvesting, for use in military applications such as unattended sensor networks, soldier systems and off-grid systems in installations, to improve the autonomy and reduce the logistical requirements of these systems. |
| **3.3.3. Fuel cell systems for use in the military environment** | Development and adaptation of fuel cell-based systems to enable small-scale electric power generation in soldier, platform, camp and forward operating base (FOB) applications. Fuel cells may use hydrogen or other alternative fuels.<br>This is part of the «New propulsion systems for manned and unmanned platforms» objective |
| **3.3.4. Systems for the microgeneration of electric power, such as microturbines or portable generator sets** | Adaptation and validation of microturbines, portable generator sets and other possible technologies other than energy harvesting and fuel cells for small-scale electric power generation, which can be used on platforms and for soldier support or in camps. |
| **3.3.5. Electric power storage systems for use in military environments** | Development of new electric power storage systems based on electrochemical technologies that have a higher charge capacity, greater flexibility in power delivery and lower weight and volume than current batteries, for use in different systems (soldier, platforms, bases and camps). These systems include new generation batteries and super capacitors, as well as integrated systems.<br>This is part of the «Power generation and energy efficiency in isolated bases and infrastructures» and «New propulsion systems for manned and unmanned platforms» objectives. |

| 3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS | |
|---|---|
| **3.4. LOGISTICS** | |
| **3.4.1. Water management systems** | Research and development of water management systems (generation, potabilisation, desalination and purification), both fixed and portable, adapted to defence needs, in particular in areas of operations and on naval platforms, to simplify logistics, ensure access to water and avoid possible contamination of water through natural or intentional causes. |
| **3.4.2. Waste management systems** | Development of waste management systems for bases and installations and naval platforms, both for the national territory and for the area of operations. This includes aspects related to waste management logistics, circular economy plans and energy recovery from waste. |
| **3.4.3. Certified non-oil based fuels** | Support to capability building of the national technological and industrial base for the development of alternative fuels to petroleum derivatives, such as third-generation biofuels or synthetic fuels, which can be used under the NATO Single Fuel Concept (SFC), reducing both energy dependence and associated greenhouse gas emissions. |
| **3.4.4. Non-SFC alternative fuels** | Support to national research and evaluation of the use of non-NATO Single Fuel Concept (non-SFC) fuels in specific applications within the defence sector. These fuels include natural gas, hydrogen (from hydrolysis or reforming), unconventional hydrocarbons (for use in fuel cells) or biogas from waste recovery, among others. |

| 4. BASES AND INSTALLATIONS | |
|---|---|
| **4.1. PROTECTION OF BASES AND INSTALLATIONS** | |
| **4.1.1. Sensor networks for the protection of land-based installations and deployments** | Research and development of technologies enabling the protection of critical bases and installations in the land-based environment, as well as troop deployments in urban areas, ports and large areas with complex terrain and lack of infrastructure. Such technologies will be based on distributed, autonomous, cooperative and remote multi-sensor land-based networks aimed at the detection of vehicles, fire direction, people, objects and activities. |
| **4.1.2. Sensor networks for the protection of maritime areas** | Research and development of technologies based on sensor and actuator networks for the surveillance and protection of maritime areas against surface and underwater threats, in particular ports and coastal environments. The use of distributed, autonomous, cooperative and remote multi-sensor networks will be considered, with the possible support of unmanned maritime systems. |
| **4.1.3. Protection against explosive-based threats to infrastructures** | Development of new passive protection elements (both fixed and portable) for deployment in areas of operation or for the protection of installations that may be subject to ballistic and blast threats, as well as the tools and knowledge necessary for modelling, simulation, experimentation and analysis of explosive-based threats. |

| 4. BASES AND INSTALLATIONS | |
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| **4.2. POWER AT BASES AND INSTALLATIONS** | |
| **4.2.1. Integrated renewable electric power generation systems for bases in the area of operations** | Development, adaptation and validation of technologies for electric power generation systems for bases and camps in the area of operations and isolated installations that allow the integration of various energy sources, increasing the capacity for efficient self-supply of electric power. Preference is given to systems based on renewable generation technologies adapted to the area of operations, supported by other generation and storage and control technologies, which ensure reliability and continuity of supply and allow the integrated generation system to act independently. Complementary aspects (standardisation, renewable resource planning and simulation tools, etc.) are also considered to ensure that these technologies can be effectively deployed in the area of operations.<br>This is part of the «Power generation and energy efficiency in isolated bases and infrastructures» objective. |
| **4.2.2. Smart electricity grids for defence** | Development, adaptation and validation of energy storage and management system technologies applied to smart electricity micro-grids to improve the quality, management and security (physical and cyber) of the grid and increase its resilience in defence installations, both in the national territory and in the area of operations.<br>This is part of the «Power generation and energy efficiency in isolated bases and infrastructures» objective. |
| **4.2.3. Self-production of fuels** | Support to national research and development of small-scale on-site fuel production systems to reduce logistic fuel needs in operations abroad, mainly based on the use of biomass (including waste), as well as hydrogen generation from various sources. |
| **4.2.4. Integrated and efficient air conditioning and DHW** | Adaptation and validation of highly energy-efficient air conditioning and domestic hot water systems for bases and camps, enabling the integration of various sources of thermal power with high energy efficiency, contributing to the reduction of total energy consumption at the installations. |

| 4. BASES AND INSTALLATIONS | |
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| **4.3. MODERNISATION OF BASES AND INSTALLATIONS** | |
| **4.3.1. Incorporation of 4.0 technologies in the Department's bases and installations and processes** | Leveraging the advances in the civil sector of the so-called 4.0 technologies to improve the functioning of the Department's bases and logistic installations, introducing improvements in all its processes through technological innovation projects, and accelerating the digital transformation process, as set out in the Ministry of Defence's Action Plan for Digital Transformation (PATD).<br>This is the core of the «4.0 technologies for the Department's digital transformation» objective. |
| **4.3.2. Smart and efficient buildings for bases and camps** | Harnessing progress in the civil sector for the construction and installation of temporary buildings and infrastructures that make up the bases and camps, adapted to the needs of defence, also facilitating interoperability in multinational operations. This includes energy efficiency technologies, mainly in the field of construction materials and innovations. |

| 5. LAND PLATFORMS | |
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| **5.1. DESIGN AND MOBILITY OF LAND PLATFORMS** | |
| **5.1.1. Design of new generation land platforms** | Research and development in the different areas that contribute to the development of new generation manned land platforms. Actions of a cross-cutting nature are envisaged in those areas that allow progress to be made in improving the structural design of land platforms, taking into account the movement dynamics and specific characteristics, including the mobility, endurance (study of shapes and simulation of behaviour in the event of explosions and ballistic impacts), habitability and payload capacity of the platforms, in order to obtain designs that optimise these parameters. |
| **5.1.2. Advanced mobility systems** | Research and development of drive train auxiliary technologies to improve the mobility of platforms in terms of terrain dominance, increasing their ability to traverse different areas. This includes systems complementary to propulsion and transmission aimed at improving the mobility of land platforms, such as innovative traction technologies (wheels and chains), advanced suspension systems or wheel hub motors. Technologies that increase the reliability and endurance of the running gear (such as anti-puncture systems) are also envisaged. |
| **5.1.3. Hybrid and electric propulsion, electrification of land platforms** | Research and development of the integration of new technologies in the fields of hybrid or all-electric propulsion, as well as electric platform architecture, including the electrification of subsystems. The integration and validation of electric power generation systems (based on batteries, fuel cells or renewables) that allow certain platform systems to operate without using the main propulsion system is also envisaged.<br><br>This is part of the «New propulsion systems for manned and unmanned platforms» objective. |
| **5.1.4. Conventional propulsion and transmission systems** | Development of conventional propulsion and transmission technologies that increase the mobility performance of the vehicle in terms of power transmitted to the running gear, enabling increased propulsion and load-carrying capacity. Improvements in the different parts of the propulsion system (engine, exhaust, energy recovery systems, etc.) are envisaged, including more efficient and lighter transmission mechanisms. |

| 5. LAND PLATFORMS | |
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| **5.2. INTEGRATED SYSTEMS** | |
| **5.2.1. Architecture and integration on land platforms** | Development of open, modular and scalable architectures that facilitate the physical and logistical integration of new systems or payloads to adapt platforms to multiple missions, extend the monitoring of platform status and improve the management of information and energy consumption relating to on-board systems, thereby improving the efficiency of the fleet and simplifying its maintenance. The systems and payloads to be integrated into land platforms also include RPAS. |
| **5.2.2. Platform crew situational awareness** | Research and development to optimise information management on platforms in order to maximise the operator's situational awareness and facilitate both vehicle control and mission accomplishment. Advances related to the integration of sensors and C4I systems on platforms, the fusion and intelligent presentation of information to the crew and the use of advanced and immersive control interfaces and driver assistance systems (automation of certain functions, human-machine control sharing, etc.) are envisaged. |
| **5.2.3. Active and reactive protection systems** | Research and development of active and reactive protection technologies, complementary to traditional passive armour, to increase the overall level of protection on platforms. On the one hand, both explosive and non-explosive reactive armour is sought, capable of reacting to the impact of projectiles, to neutralise or attenuate the damage they cause to platforms. On the other hand, active protection technologies are pursued that enable the detection, identification, tracking or neutralisation of enemy projectiles before they hit the platform, giving priority to the hybridisation of sensors to detect and track RAM (rockets, artillery and mortar shells) threats. This also includes the integration or installation of this equipment into the platform's self-protection system. |

| 5. LAND PLATFORMS | |
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| **5.3. LAND ROBOTICS** | |
| **5.3.1. Conversion of platforms or groups of platforms into unmanned systems** | Research and development to convert one or more existing military vehicles into unmanned platforms so that they can be remotely controlled individually or in convoy form. The vehicles will be able to operate by teleoperation or with higher levels of autonomy, enabling military missions to be conducted without the need for human presence in the vehicles. Standardised automation kits comprising sensors, effectors, communication equipment, control electronics and human-machine interfaces are expected to be developed, which can be easily adapted to different types of platforms and allow the system to be remotely controlled. In the particular case of convoys, it will be possible to combine unmanned and manned platforms, including configurations in which the manned vehicles do not lead the convoy, and the role and number of vehicles in the system can be flexibly adapted.<br><br>This is part of the «Robotics – Unmanned land platforms for defence missions» objective. |
| **5.3.2. Advanced functionalities in UGV based on robotic autonomy** | Research and development of technological solutions to improve the autonomous functionalities of robotic systems used in defence. In particular, the focus is on achieving increased levels of autonomy in unstructured environments (navigation and positioning in the absence of GNSS, automatic path generation, obstacle detection and avoidance, complex manoeuvres, etc.), cooperative operation between platforms (autonomous tracking, swarm formation, automatic task distribution, coordinated manoeuvres, etc.), as well as interoperability aspects in communication and the use of robotic architecture standards adapted to defence needs.<br><br>This is part of the «Robotics – Unmanned land platforms for defence missions» objective. |
| **5.3.3. Robotics for specific defence missions** | Research and development to adapt existing robotic systems to the requirements of different military missions, adjusting the functionalities of the platform to the specific requirements of each mission. This adaptation will affect both platforms and their payloads, which may include sensors, actuators, communication links, algorithms, improved interfaces, etc. The focus is on applications in support of C-IED/CBRN, surveillance and reconnaissance, soldier logistics support, search and rescue, engineering/sapper operations, medical evacuation, operations in urban environments, emergency intervention and combat, ensuring in the latter case that a human operator always maintains control over the robot's armament.<br><br>This is part of the «Robotics – Unmanned land platforms for defence missions» objective. |

| 6. NAVAL PLATFORMS | |
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| **6.1. NAVAL PLATFORM DESIGN** | |
| **6.1.1. Surface naval platform design** | Research and development aimed at designing the future generation of manned surface naval platforms to improve operational and navigational performance in response to future threats. These aspects will be related to hydrodynamic properties (living works), aerodynamic properties (dead works), structural properties, compartmentalisation, buoyancy, stability, platform functionality, payload capacity, etc., including the incorporation of new materials, new hulls (inverted bows, trimarans, pentamarans, etc.), and new superstructures. |
| **6.1.2. Underwater naval platform design** | Research and development activities aimed at supporting the design of the future generation of manned underwater platforms to provide improved operational and navigational performance in response to future threats. These aspects will be related to hydrodynamic and structural properties, functionality, stealth, manoeuvrability, autonomy, resistance to impacts and leaks, fire, etc. |
| **6.1.3. Surface and underwater naval platform invisibility** | Research and development on aspects related to improving the invisibility of surface and underwater military platforms to reduce their exposure to potential external threats. Advances related to the use of active and passive countermeasure systems on board the vessels are considered, focusing on the reduction of magnetic, infrared, acoustic, seismic and pressure signatures, through the use of new materials, hydro-aerodynamic shapes, thermal and acoustic insulation, damping systems to avoid on-board vibration propagation, etc. |
| **6.1.4. Safety on board platforms** | Development of technological solutions that improve both human safety on board and the safety of the Navy's own platforms in the event of breakdowns, increasing operational effectiveness, platform resistance and recovery in adverse conditions. |

| 6. NAVAL PLATFORMS | |
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| **6.2. NAVAL CONTROL, POWER AND PROPULSION** | |
| **6.2.1. Naval platform propulsion systems** | Research and development aimed at supporting the design of new propulsion systems with improved performance in terms of power, efficiency and reduction of pollutant gases (COx, NOx, etc.) to improve the responsiveness of platforms. Aspects related to the improvement of conventional propulsion (diesel, petrol engines, etc.), alternative propulsion (biofuels, liquefied natural gas, gas turbines), diesel-electric hybrid, other renewable energies (wind, solar, etc.), as well as thrusters (conventional propellers, CLT, water jets, Voith Schneider propellers, azimuth thrusters, etc.) are considered. |
| **6.2.2. Naval platform manoeuvrability** | Research and development of platform control systems (dynamic positioning, bow thrusters, rudders, servomotors, etc.) to improve the positioning and manoeuvrability of platforms used in defence. |
| **6.2.3. Electric power generation systems on naval platforms** | Development of shipboard electric power generation and storage systems, including the integration of new batteries and fuel cells adapted to maritime environments. Design of new equipment, systems and electrical wiring elements to redesign the electric power plant of the vessels, improving energy efficiency on board. Research into aspects related to super-conductivity in both power generation and distribution systems.<br><br>This is part of the «New propulsion systems for manned and unmanned platforms» objective. |

| 6. NAVAL PLATFORMS | |
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| **6.3. INTEGRATED SYSTEMS ON NAVAL PLATFORMS** | |
| **6.3.1. Evolution of naval platform combat systems** | Development and evolution of the architecture and functionalities of naval platform combat systems to facilitate their adaptation to the increasing variety and sophistication of threats, the increased volume of data and information to be processed and the agility to make decisions in real time, while maintaining their system-of-systems approach and security requirements. |
| **6.3.2. Integration of unmanned vehicles on surface platforms** | Research and development aimed at the integration of unmanned vehicles on the mother ship, both from a control point of view (interoperability) and from a layout point of view (space on board for storage, launching and retrieval).<br>This is part of the «Robotics – Unmanned underwater and surface vehicles for defence missions» objective. |
| **6.3.3. Maritime environment knowledge support system** | Research and development of mathematical models and algorithms to characterise and predict the evolution of maritime environments (atmospheric, oceanic, surface, etc.), in order to support the accomplishment of military missions in these surroundings. |

| 6. NAVAL PLATFORMS | |
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| **6.4. UNMANNED NAVAL VEHICLES** | |
| **6.4.1. Technologies and systems aimed at unmanned underwater vehicles** | Research and development of technologies, sensors, payloads, command and control systems, propulsion, positioning and on-board power generation/control, navigation and communications systems associated with UUVs (unmanned underwater vehicles) such as AUVs (autonomous underwater vehicles) and underwater ROVs (remotely operated vehicles), for use in military missions.<br>This is part of the «Unmanned underwater and surface vehicles for defence missions» objective. |
| **6.4.2. Technologies and systems aimed at unmanned surface vehicles** | Research and development of technologies, sensors, payloads, command and control systems, positioning, navigation and communications systems associated with USVs (unmanned surface vehicles) for use in military missions.<br>This is part of the «Robotics – Unmanned underwater and surface vehicles for defence missions» objective. |
| **6.4.3. Remotely manned naval vehicle swarms** | Research and development of robust control technologies to reliably control a set of networked USVs and UUVs operating as a swarm in a common mission. Consideration should also be given to collaborative operations between these remotely operated or autonomous naval vehicles with any of the other domains (air or land).<br>This is part of the «Robotics – Unmanned underwater and surface vehicles for defence missions» objective. |

| 7. AIR PLATFORMS | |
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| **7.1. DESIGN OF AIR PLATFORMS** | |
| **7.1.1. Development of new generation manned air platforms** | Research and development in the different areas contributing to the development of new generation manned platforms. Actions of a cross-cutting nature are envisaged in those areas that facilitate progress to improve the capabilities of future platforms, such as the design of platforms geared towards low observability, the orientation of platforms towards the system-of-systems concept, the use of new materials to improve performance and the improvement of their life-cycle. |
| **7.1.2. Development of rotary wing platforms** | Research and development in the different areas contributing to both the improvement and the development of new rotary wing platforms. Cross-cutting actions are envisaged in those areas that allow progress to be made in the design of rotary wing platforms, integrating new concepts that, on the one hand, improve the performance of current platforms and, on the other, explore new usage concepts, reduced signature, increased protection and improved life-cycle. |

| 7. AIR PLATFORMS | |
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| **7.2. POWER AND PROPULSION** | |
| **7.2.1. Application of advanced electric power plant and electronic management of platform systems and status** | Specific application of technological developments in the production and storage of electric power (advanced batteries, fuel cells, supercapacitors, etc.) to manned and unmanned air platforms.<br>Also included are research and development of integrated power management and control systems that respond to the increased power demand of the platforms, improving the grid's transmission and monitoring capacity.<br>This is part of the «New propulsion systems for manned and unmanned platforms» objective. |
| **7.2.2. Improved propulsion and power systems on air platforms** | Research and development aimed at supporting the design of new propulsion systems that improve both performance and operational characteristics in terms of power, efficiency and life-cycle optimisation. Actions are considered that contribute to the development of new engine architectures, as well as to the concept of a more electric engine, and also to the reduction of the thermal signature and the improvement of the propulsion plant's life-cycle. |

| 7. AIR PLATFORMS | |
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| **7.3. AVIONICS/C4I FOR AIRBORNE SYSTEMS** | |
| **7.3.1. Integrated avionics systems** | Research and development of technologies relevant to the avionics of manned and unmanned air platforms, making use of modular and integrated avionics. This includes technologies enabling the integration, management, processing and presentation of aeronautical information from sensors, communication equipment, navigation, guidance and control equipment, as well as actions to increase the autonomy of both manned and unmanned platforms. |
| **7.3.2. Airborne mission systems** | Development of technological solutions to improve the capability to perform and accomplish the missions for which both manned and unmanned platforms are used. Actions are envisaged to improve the situational awareness of platforms, the management of the equipment deployed, operator decision-making and human-machine integration. |
| **7.3.3. Aeronautical system-of-systems including the swarm concept** | Research and development of robust control technologies supporting the formation of networked swarms of manned and unmanned systems acting collaboratively to accomplish defence missions. The interaction of these platforms with the other actors present in the field of operations is also envisaged, favouring the integration of air platforms with the operating environment.<br><br>This is part of the «Robotics – Innovative applications of RPAS in defence» objective. |
| **7.3.4. Alternative navigation systems to GNSS signals** | Research and development of navigation, localisation and indoor and confined area mapping technologies using mini-micro-UAVs (MAVs), which can support the development of defence missions (e.g., inspection of disaster areas, surveillance and special operations). Actions are envisaged to improve the navigation of both manned and unmanned platforms, decreasing the dependence on GNSS signals by using alternative navigation systems based on different technologies (e.g., imagery).<br><br>This is part of the «Robotics – Innovative applications of RPAS in defence» objective. |
| **7.3.5. Manned, unmanned air traffic management systems and integration of RPAS in non-segregated airspace** | Development of technological solutions related to air traffic management (ATM) systems, both fixed and deployable, including the unmanned traffic management (UTM) concept. This includes activities that enable the integration of RPAS in non-segregated airspace, including Sense and Avoid technologies as well as certification and operational aspects. |

| 7. AIR PLATFORMS | |
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| **7.4. RPAS** | |
| **7.4.1. Class II and III RPAS** | Development of technologies related to Class III (strategic-operational and combat) and Class II (tactical) unmanned air platforms, the latter including both fixed wing and rotary wing platforms. This includes those critical technologies associated with the improvements in capabilities required of the new platforms, such as those related to their design, development, manufacturing and testing processes, as well as the processes associated with the integration of armament and improvement of the ISTAR capabilities of these platforms.<br><br>This is part of the «Robotics – Innovative applications of RPAS in defence» objective. |
| **7.4.2. Class I RPAS** | Research and development for the adaptation to defence needs of Class I and MICRO, MINI and SMALL category unmanned air platforms, both fixed and rotary wing, including both the airborne vehicle and its subsystems (structure, control, guidance and navigation, payload, etc.), and their integration, as well as ground control and information management equipment. This also includes the development of components, subsystems and systems and their validation in relevant environments, to broaden the uses of these platforms in the field of the Armed Forces.<br><br>This is part of the «Robotics – Innovative applications of RPAS in defence» objective. |

| 8. SPACE SYSTEMS | |
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| **8.1. SPACE SEGMENT** | |
| **8.1.1. Devices and systems making up the satellite structure** | Development and improvement of the subsystems making up a satellite, irrespective of the type of payload, so that they are adapted to defence requirements. Aspects related to the use of solar panels, miniaturisation of components, improvement of power equipment, improvement of on-board processing algorithms and control and potential HANE (high-altitude nuclear explosion) protection are considered. |
| **8.1.2. On-board satellite technologies for SATCOM** | Development and adaptation of communication elements for the new generation of military communication satellites (SPAINSAT NG I and SPAINSAT NG II), including the use of bi-directional X, Ka and UHF frequencies and sophisticated anti-jamming and anti-spoofing protection, to ensure the continuity of secure communication in theatres of operation. |
| **8.1.3. On-board satellite technologies for Earth observation space systems (SEOT)** | Development and improvement of optical and radar technologies on board Earth observation satellites (telescopes, optical and infrared cameras or SAR technology) to achieve the levels of resolution required for defence applications, as well as the incorporation of advanced on board data processing capabilities to reduce the data capacity sent to Earth and the response time. |
| **8.1.4. High-altitude pseudo-satellites** | Development of HAPS (high-altitude pseudo-satellites) adapted to defence missions, capable of providing communication and surveillance in certain areas for non-extended missions with reduced coverage or in support of communication and Earth observation satellites.<br><br>This is part of the «Space – Use of small satellites and pseudo-satellites in defence applications» objective. |
| **8.1.5. Small satellites** | Development of small satellites adapted to defence missions for use in a specific geographic area (individually, in constellations or as distributed satellites), in order to take advantage of their advantages in terms of cost and time reduction in satellite development and deployment, and in terms of reducing revisit times to acquire data on the same location, providing complementary capabilities to large satellites.<br><br>This is part of the «Space – Use of small satellites and pseudo-satellites in defence applications» objective. |

| 8. SPACE SYSTEMS | |
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| **8.2. GROUND SEGMENT** | |
| **8.2.1. Ground stations for Earth observation space systems (SEOT)** | Development and optimisation of the ground segment of the Earth observation systems for the reception and processing of satellite imagery from optical and SAR radar sensors, including the integration of both of them to make them more informative and available. |
| **8.2.2. Ground stations for SATCOM systems** | Development and adaptation of the ground segment of the SATCOM military satellite communications system to take full advantage of the capabilities of the new generation of SPAINSAT NG satellites. Since the new generation will work in X-band, military Ka-band and UHF band, the ground stations will have to be adapted to these changes, i.e., transmit/receive, telemetry and telecontrol antennas located in the control centres. In addition, modems will need to be adapted to take advantage of the beam hopping characteristics of this new generation. |
| **8.2.3. SST or SSA systems for surveillance and tracking of space debris** | Development and improvement of space surveillance and tracking systems (radars, telescopes and all types of optical sensors for the observation of satellites and other objects such as space debris), as well as mitigation measures for the removal of space debris within the SST programme, in particular debris which could impact defence assets, to avoid loss of capabilities or damage to space assets. |

| 8. SPACE SYSTEMS | |
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| **8.3. USER SEGMENT** | |
| **8.3.1. GNSS receivers** | Development of Global Navigation Satellite System (GNSS) receivers with advanced performance, enabling highly reliable and robust geolocation and radio navigation in tactical environments where satellite coverage is available. On-board receivers on platforms (land, naval or air), missiles and soldier-portable equipment with multi-constellation capabilities and use of GNSS signal augmentation systems (SBAS – EGNOS) are envisaged. In the case of GALILEO PRS receivers for defence use, progress is required in terms of resilience, robustness, anti-jamming, anti-spoofing and anti-meaconing features, among others. |
| **8.3.2. SATCOM user terminals** | Development and optimisation of SATCOM user satellite terminals to adapt them to the capabilities offered by the new generation of SPAINSAT NG government satellites, giving the performance required by defence concerning robustness, security, confidentiality, accuracy, reliability, flexibility or navigation in the absence of GNSS in short periods of time in order to remain satellite pointed, and addressing aspects of miniaturisation or evolution towards dual equipment. All types of terminals are considered, whether they are on board mobile platforms used in defence (land, air and naval), as well as semi-static, portable or manpack type. |
| **8.4. COMPLEMENTARY SYSTEMS** | |
| **8.4.1. Small satellite launchers** | Development of technological solutions capable of launching small satellites into orbit for defence purposes, reducing deployment time and cost compared to existing solutions. Rocket-based solutions are considered, whether propelled by liquid or solid fuel, as well as ground, aircraft or hot-air balloon launches. The possibility of multi-launching is also considered given the reduction in size and power required.<br><br>This is part of the «Space – Use of small satellites and pseudo-satellites in defence applications» objective. |

| 9. SOLDIER | |
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| **9.1. SOLDIER SYSTEM** | |
| **9.1.1. Passive soldier protection systems** | Research and development of technologies to improve the soldier's protection against projectiles, fragments, stab wounds, etc. and to reduce the trauma caused by the aforementioned threats. These technologies will be the basis for the procurement of systems and elements of passive soldier protection (bullet-proof vest, helmet and limb protection) for subsequent integration into the soldier system.<br>This is part of the «Materials – Passive platform and soldier protection» objective. |
| **9.1.2. Signature reduction systems through materials** | Research and development of technologies enabling the radar, IR, visible, etc. signature of the soldier to be reduced and blended in with the surrounding environment, hampering the potential enemy's detection capability, while maintaining an acceptable level of mobility and comfort. This is part of the «Materials – Reduction of platform and soldier signatures» objective. |
| **9.1.3. Soldier energy systems** | Development of a common architecture, including interfaces and a smart management system, to increase the energy efficiency of the dismounted soldier subsystems. The integration and validation of new power storage and generation systems adapted to the soldier›s mission requirements, both new generation batteries and other alternative sources, is also envisaged.<br>This is part of the «Technologies for the dismounted soldier» objective. |
| **9.1.4. Improved soldier comfort** | Research and development of solutions to improve the thermal comfort of the soldier in all environmental conditions. This involves solutions to release the heat accumulated by the soldier in extremely hot environments and maintain it in extremely cold conditions to avoid heat stroke or episodes of hypothermia without significantly reducing the soldier's operational capabilities.<br>This is part of the «Technologies for the dismounted soldier» objective. |

| 9. COMBATIENTE | |
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| **9.1. SOLDIER SYSTEM** | |
| **9.1.5. Reduction of the soldier's load/exoskeletons** | Research into technologies (lightweight materials, miniaturised systems, wearables attached to the soldier's body, etc.) that alleviate the load that soldiers must carry (weapons, ammunition, equipment, etc.), improving their mobility and endurance and alleviating fatigue and tiredness, which can lead to injury.<br>One of the most representative systems in this field are exoskeletons, which can be upper, lower or full body exoskeletons to assist the soldier in various types of tasks (work involving handling loads, carrying equipment, deactivating explosives, handling weapons, etc.) while assisting the individual's movement. Due to their higher level of technology readiness and simplicity. Nonetheless, the focus will be mainly on passive exoskeletons, active systems may also be considered according to their progress, their development being more complex as they require a combination of multiple technologies (materials, sensors, actuators, communications, algorithms, batteries, etc.).<br>This is the core of the «Exoskeletons for defence applications» objective. |
| **9.1.6. Soldier sensorisation, computing and connectivity** | Research and development of technological solutions to enable soldiers to acquire, process and deliver information so that they acquire the necessary situational awareness to carry out their mission. This includes the development of standardised open architectures (SOA) to facilitate the integration and exploitation of information.<br>This is part of the «Technologies for the dismounted soldier» objective. |
| **9.1.7. Soldier navigation capabilities in the absence of GNSS** | Research and development of technologies that provide navigation capabilities to the soldier, both indoors and outdoors, in the absence or degradation of the GNSS signal.<br>This is part of the «Technologies for the dismounted soldier» objective. |

| 9. SOLDIER | |
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| **9.2. HUMAN FACTORS** | |
| **9.2.1. Monitoring and improvement of the soldier's performance** | Development of tools to improve the psycho-physical aspects of the soldier: personalised physical training, psychological assessment and preparation, operational training through simulation, etc., including the acquisition of socio-cultural knowledge specific to the theatre of operations. The development of biosensors for measuring physiological parameters is also envisaged. These devices ought to be easily adaptable and of low energy cost, capable of sending data in real time for monitoring the physical condition of the soldier, both in training and in real operations. |
| **9.2.2. Advanced human-machine interfaces** | Development of human-machine interfaces that enhance the soldier's skills and situational awareness, are intuitive and easy to use, allowing learning by doing and mitigating the problem of information overload. |
| **9.2.3. Integration of people on platforms** | Research and development of solutions that improve all aspects (ergonomics, psychological effects, etc.) related to the integration of people on the various military platforms. |
| **9.2.4. Human-unmanned system interaction in missions** | Research and development of technological solutions to facilitate human-unmanned systems working together as part of a team (human-machine teaming). The objective is to optimise the integration between both agents, to achieve the most efficient interaction possible, in turn allowing for a greater introduction and implementation of these systems in military missions. To this end, progress must be made in the decision-making autonomy and situational awareness of robots so that they can understand and execute complex instructions, as well as in advanced interfaces that enable simplified and efficient control, exploring new technologies that facilitate human-machine communication. |

| 9. SOLDIER | |
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| **9.3. HEALTH ISSUES** | |
| **9.3.1. Early medical response** | Tools and training methodologies that enable non-specialised (non-healthcare) personnel to carry out effective Tactical Combat Casualty Care (TCCC) to mitigate the impact of serious injuries in the area of operations (shrapnel penetration, burns, blast trauma, etc.) and to stabilise the casualty.<br><br>Advanced medical evacuation solutions are also envisaged to enable rescue in areas of difficult access and the transfer of victims in the best possible physiological conditions, so that they can be treated in a suitable health centre. The development of innovative telemedicine tools for use at Armed Forces platforms and installations, when immediate transfer is not possible, is also of interest.<br><br>Finally, modular tools and installations that facilitate coordinated and efficient medical assistance in the deployed areas (role 2) are also considered |

| 10. CBRNe | |
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| **10.1. C-IED TECHNOLOGIES** | |
| **10.1.1. Remote sensing of explosive ordnance and substances in land-based environments** | Technologies for remote sensing of improvised explosive devices (IEDs) by detecting the device or its elements (switch, power source, initiator, main charge and container), or traces of the explosive material. Developments to be integrated on board UAV or UGV platforms for the enhanced safety of operational personnel are envisaged. Also included are technologies for indirect detection of buried or hidden IEDs by detecting disturbances in the natural environment, such as earth movements, changes in soil density, changes in vegetation, etc.<br>This is part of the «Advanced land-based IED detection systems» objective. |
| **10.1.2. Remote sensing of explosive atmospheres** | Development of technologies and systems for remote detection of vapour emitted by explosive substances, providing early warning of explosion risk. These are highly sensitive sensors (given the low vapour pressure of explosive substances). Devices and sensor networks capable of operating remotely to avoid the exposure of operating personnel are included.<br>This is part of the «Advanced land-based IED detection systems» objective. |
| **10.1.3. Advanced forensic analysis techniques** | Development of technological solutions that improve the collection, analysis and exploitation of all information associated with an explosive ordnance incident, including the selection and collection of evidence in a post-explosion scenario while minimising risks, so that the information can be used to improve all stages of the process of countering the IED threat (damage mitigation measures for platforms and people; combating the networks responsible for placing the ordnance, tactics, techniques and procedures, etc.). |
| **10.1.4. Detection and neutralisation of explosive threats in maritime environments** | Research and development of technological solutions related to the detection and neutralisation of explosive-based threats (WBIED – water-borne improvised explosive device, naval mines, divers carrying explosives, etc.) that could attack naval platforms (surface and underwater), maritime infrastructures, port accesses and installations, etc., in all weather and maritime conditions. |

| 10. CBRNe | |
|---|---|
| **10.1. C-IED TECHNOLOGIES** | |
| **10.1.5. Protection against small RPAS-type threats** | Research and development of technological solutions aimed at detecting, identifying, classifying and neutralising threats arising from the use of RPAS against fixed and mobile installations in the different environments in which the Armed Forces operate, both in the land and sea domains. To this end, actions are envisaged that will enable progress to be made in the actions described in both fixed and portable counter RPAS systems.<br><br>This is the core of the «Counter RPAS systems» objective. |
| **10.1.6. Exploitation of information to combat networks responsible for the IED threat** | Development of technological solutions aimed at exploiting multiple sources of information and building military intelligence to neutralise networks responsible for placing IEDs. These networks include the pool of resources, people and activities related to the financing, organisation, recruitment, indoctrination, supply, execution and detonation of an IED.<br><br>This is part of the «AI – Intelligent analysis of multiple sources of information for decision support» objective. |

| 10. CBRNe | |
|---|---|
| **10.2. CBRN DEFENCE** | |
| **10.2.1. Remote or stand-off CBRN detection** | Research and development of technologies with potential application in the remote or stand-off detection of CBRN agents, as well as detection systems based on the use of networked sensors, with reduced economic and energy costs, which enable the detection and monitoring of toxic clouds and transmit information to the command in real time for continuous monitoring of areas of operations or critical zones.<br><br>This is part of the «CBRN threat control» objective. |
| **10.2.2. Point CBRN detection and identification** | Research and development of technologies for portable or hand-held CBRN detection and identification equipment that improves the performance of existing equipment; greater precision and lower energy requirements for radiological agents; higher sensitivity and identification capacity; and smaller size and lower energy requirements for chemical agents. In the case of biological detection/identification, in addition to the foregoing, there is a need for rapid and automatic technologies that require little or no sample handling. The design and development of bench-top analytical equipment and deployable CBRN laboratories as well as systems for CBRN sample collection and management for forensic analysis are also envisaged. |
| **10.2.3. CBRN decontamination** | Research and development of new systems for CBRN decontamination of areas, vehicles, equipment and personnel, which are safe for both personnel and the environment and enable a rapid and safe recovery of the affected surroundings. Technologies for universal and effective use against the wide range of CBRN agents, which do not require liquids, or minimise their use, to alleviate the logistical problem of relying on large volumes of water or organic liquids. Technologies compatible with sensitive material (electronic equipment, NBC protective suits, platforms, etc.) that enable its effective use after decontamination. This includes solutions capable of abating or neutralising CBRN atmospheres to prevent their dispersion.<br><br>It also includes the development of technologies or systems to control the effectiveness of decontamination processes.<br><br>This is part of the «CBRN threat control» objective. |

| 10. CBRNe | |
|---|---|
| **10.2. CBRN DEFENCE** | |
| **10.2.4. Smart CBRN personal protective equipment** | Research and development of new materials, new designs and new mechanisms for the procurement of more ergonomic, lighter personal protective equipment, offering better CBRN protection and integrating advanced functions, such as sensing and self-decontaminating capabilities, while maintaining the soldier's comfort.<br>This is part of the «CBRN threat control» objective. |
| **10.2.5. Collective CBRN protection** | Research and development of environmental threat filtration or elimination systems that protect groups of people against all types of agents, including industrial toxins, in all types of environments. To enhance the protection capability, the systems shall be provided with sensing or self-decontamination functions against CBR agents. The aim is also to optimise the use of these systems by integrating monitoring indicators to warn of the exhaustion or saturation of filters in order to ascertain their useful life or the operational level of the equipment. |
| **10.2.6. Medical countermeasures against CBRN agents** | Research and development of technologies for new therapeutic and prophylactic medical treatments (antidotes, vaccines, decorporating agents, etc.) and for rapid and early diagnosis of poisoning and infectious diseases, mainly contagious ones, to help curb potential epidemics. Technologies to improve the performance of existing medical countermeasures, such as drug-delivery devices, etc. |
| **10.2.7. CBRN situational awareness** | Research and development of data fusion and integration algorithms in CBRN incident management software. Development of information systems for the management of this type of incident by command and control, modelling and simulation tools to predict the evolution of a contamination cloud and locate the origin of the threat, integrating data from external factors such as meteorological ones. This line includes health, symptomatological and epidemiological surveillance systems that manage information in a comprehensive manner. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.1. C4I INFORMATION SYSTEMS** | |
| **11.1.1. Advanced C2 systems functionalities for planning and conducting military operations** | Research and development of new functionalities of command-and-control information systems for military operations, at strategic, operational and tactical levels, covering the different military functions, to avail of improved tools for the planning and conducting of operations, automated and smart decision-making support features, as well as a better situational awareness. |
| **11.1.2. C4I systems interoperability** | Implementation of new interoperability standards and tools that enable the integration of JISR data and information and the interconnection between the national and international C4I systems of the different armies. Also included is the creation of tools to maintain the capacity for interoperability between simulators and C2 systems, increasing the possibility of training forces using these C2 systems. |
| **11.1.3. Open-source intelligent analysis for defence purposes** | Development of technological solutions that enable the analysis and automatic extraction of information from open-source intelligence (OSINT), with a view to creating intelligence to support decision-making in different domains of interest to defence.<br><br>This is part of the «AI – Intelligent analysis of multiple sources of information for decision support» objective. |
| **11.1.4. Intelligent exploitation of multiple information sources** | Development of technological solutions that enable the cognitive fusion of information from multiple heterogeneous sources and the creation of military intelligence to support decision-making in different domains of interest to defence. The aim is to reproduce by computational means a level of cognitive reasoning close to that of the human mind, to answer complex, more or less abstract or ambiguous questions, correlating multiple variables or establishing relationships between them.<br><br>This is part of the «AI – Intelligent analysis of multiple sources of information for decision support» objective. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.2. TACTICAL COMMUNICATION** | |
| **11.2.1. Software-defined radio and cognitive radio** | Research and development of new waveforms of wireless communication to guarantee secure information exchanges on national and international operations, as well as to address interoperability issues and bandwidth limitations caused by new requirements for data transmission (images, video, etc.) from multiple platforms and sensors (UAVs, UGVs, etc.), both in LOS and BLOS, together with frequency spectrum management for radio transmission in an increasingly congested environment.<br>This is the core of the «Military communications in complex environments» objective. |
| **11.2.2. Digital tactical links communications and their integration into platforms** | Develop solutions and implement international tactical data link standards (Link 16/Link 22) for the exchange of information and its use in cooperative operations, as well as the exchange of tactical information between platform mission systems to maintain and improve NATO interoperability. Provide forces with a TDL (tactical data link) solution that can be easily integrated into tactical platforms, feasible and aligned with NATO's TDL Migration Strategy, facilitating its integration into multi-link networks established in theatres of operations, thus achieving interoperability between platforms and allies. This also includes VMF-based solutions for tactical environments and their integration with platform systems (tactical radios and mission/information systems) for digital data exchange between land, naval and air forces. |
| **11.2.3. Connectivity and computing architectures** | Development of new connectivity and network computing architectures to enable military units to take advantage of both cloud-based and tactically deployed resources at all times and in all places, thereby ensuring they always obtain the right information as soon as possible. With this objective, highly flexible and resilient software-managed network solutions are sought, capable of reconfiguring and adapting to the characteristics of the environment and the needs of the mission, enabling high connectivity of all types of devices and systems deployed at tactical level with real-time information exchange and the possibility of intelligent information processing at the final level, complementing the information available in the cloud. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.2. TACTICAL COMMUNICATION** | |
| **11.2.4. New generation mobile networks** | Development of technological solutions applied to military problems requiring low latency and transmission of large amounts of information in real time, based on communications systems that make use of new generation (5G) mobile networks for voice and data transmission using IP protocols securely over long distances, with networks that can be deployed quickly and easily and small, lightweight user terminals.<br><br>Taking advantage of the possibilities offered by 5G technology in terms of virtualisation of network services, the search for network configurations optimised for each type of military application that makes use of 5G will be investigated. Security solutions will also be investigated to minimise the risks and vulnerabilities that may affect this type of network.<br><br>This is part of the «4.0 technologies for the Department's digital transformation» objective. |
| **11.2.5. Acoustic and optical communication in the underwater environment** | Research and development of underwater acoustic communication technologies and systems that contribute to the improvement of current performance, through the creation of new low-distortion modulation techniques, interference suppression mechanisms, recovery from fading, etc. Research and development in underwater optical communication technologies is also contemplated, with the aim of improving transmission bandwidth and range, reducing signal distortion, all to improve communication between platforms, networks and infrastructures.<br><br>This is part of the «Robotics – Unmanned underwater and surface vehicles for defence missions» objective. |
| **11.2.6. Optical communication in free space** | Research and development of technologies related to optical communication in free space, so that it will be possible to have systems and networks adapted to defence needs that leverage their advantages in terms of bandwidth, low detection, interception or resistance to interference. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.3. SIMULATION** | |
| **11.3.1. Advanced training through simulation** | Development of innovative solutions based on the use of simulation systems that allow optimal preparation and training of Armed Forces personnel in their cognitive, physical and psychological dimensions, covering issues related to the doctrine for the execution of operations, the use of material means (platforms, armament, etc.) or the recreation of conditions close to those of actual operations, in the land, sea, air and cyberspace domains.<br><br>This is the core of the «Advanced training through simulation» objective. |
| **11.3.2. Interoperability between simulators** | Development of technological solutions based on interoperability standards that allow different simulators to work together in exercises.<br><br>The implementation of interoperability standards in simulation systems facilitates the extension of the training capacities of the systems, making it possible to bring together in a single simulation exercise the different target audiences of each of these systems that initially operated in isolation.<br><br>This is part of the «Advanced training through simulation» objective. |
| **11.3.2. Simulation as a decision-making tool** | Development of simulation-based technological solutions to support problem-solving and decision-making in capability acquisition and development, requirements analysis, concept and doctrine development and experimentation, operational (crisis and advance) and strategic planning, operational support and mission rehearsal, among others. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.4. INFORMATION AND SYSTEMS SECURITY** | |
| **11.4.1. Automation of actions against cyber-attacks** | Development of tools adapted to defence specificities to automate protection against cyber-attacks, both in information systems and in the weapon systems themselves. |
| **11.4.2. Cyber intelligence for predictive analysis of vulnerabilities** | Development of technological solutions to collect information on cyber threats from multiple sources, so that intelligence can be generated for pattern recognition to anticipate future attacks.<br>This is part of the «Solutions for cyber operations» objective. |
| **11.4.3. Technologies in support of cyber operations** | Development of technological solutions for an active, balanced and proportional response to the attack undergone, under the principle of self-defence within the type of CNA (computer network attack) operations aimed at disrupting, denying, degrading or destroying information flowing through enemy systems.<br>This is part of the «Solutions for cyber operations» objective. |
| **11.4.4. Software and hardware cryptological devices to increase communication security** | Development of the appropriate encryption technologies to increase communication security and sovereignty, specifically considering interoperability between cryptological devices from different manufacturers. Aspects related to key distribution technologies will also be taken into account, including the latest technological developments which, once they have sufficient capability and security, can be deployed in defence applications. |
| **11.4.5. Development of secure interconnection capabilities of multi-level systems** | Development and research into information systems and mechanisms that allow operation at different levels of security, preventing the transfer of sensitive or classified information to other unauthorised or less restrictive levels. |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | |
|---|---|
| **11.5. APPLICATION OF ICT ADVANCES TO DEFENCE** | |
| **11.5.1. Advances to mitigate risks and limitations in the use of AI in defence** | Research and development of algorithms and tools to reduce or mitigate the risks and limitations associated with their extensive use in defence systems, as well as malicious use of these technologies by other parties. This includes the lack of clarity in the decision-making logic of many AI algorithms, particularly deep learning algorithms; the difficulty of detecting fake multimedia content generated from other similar multimedia content; the lack of robustness or malicious introduction of training data that alter or bias the learning process; the security and privacy of data throughout the process; the unpredictable behaviour of algorithms in novel situations for which they have not been prepared; the potential cascading failures when incorporating multiple AI-based software modules in a complex system, such as those used in defence; the need for large volumes of data to train algorithms; and the complexity of incorporating ethical criteria into decision-making processes, among others.<br>This is part of the «AI – Intelligent analysis of multiple sources of information for decision support» objective. |
| **11.5.2. Applications of biometric technologies** | Development of technological solutions aimed at specific defence applications, which make use of the latest advances in biometric technologies, such as forensic analysis of IED incidents, authentication in information systems or perimeter security in military installations. |
| **11.5.3. Applications of speech and text analysis technologies** | Development of technological solutions aimed at specific defence applications, which make use of the latest advances in natural language processing technologies.<br>This is part of the «AI – Intelligent analysis of multiple sources of information for decision support» objective. |

# Simplified list of R&D lines

| | |
|---|---|
| **1. WEAPONS AND AMMUNITION** | |
| **1.1. WEAPONS AND AMMUNITION TECHNOLOGIES** | |
| 1.1.1. | Improved performance of ammunition through effects and activation technologies |
| 1.1.2. | Improvements in ammunition propulsion technologies |
| 1.1.3. | Improved safety in the use of weapons and ammunition through control systems, insensitive munitions and other specific measures |
| 1.1.4. | Improved performance of munitions through guidance and advanced control devices |
| **1.2. WEAPONS INTEGRATION AND INTEROPERABILITY TECHNOLOGIES** | |
| 1.2.1. | Technologies for improved integration and interoperability of weapons with the soldier system |
| 1.2.2. | Technologies for improved integration and interoperability of weapons with platforms and command and control systems |
| **1.3. APPLICATION AND TECHNOLOGY-SPECIFIC WEAPONS** | |
| 1.3.1. | High-power laser directed-energy weapons |
| 1.3.2. | RF directed-energy weapons |
| **1.4. LIFE-CYCLE SUPPORT TECHNOLOGIES FOR WEAPONS AND AMMUNITION** | |
| 1.4.1. | Management and control of ammunition life-cycle through support tools |
| 1.4.2. | Improvement of efficiency and reduction of effects on health and the environment in the production, demilitarisation, transport and storage of weapons and ammunition |

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| **2. SENSORS AND ELECTRONIC SYSTEMS** | |
| **2.1. ELECTRONIC TECHNOLOGIES** | |
| 2.1.1. | High-performance RF devices, modules and antennas |
| 2.1.2. | Application of photonics technology to RF systems |
| 2.1.3. | SMRF architecture |
| **2.2. RADAR** | |
| 2.2.1. | Non-cooperative target identification (NCTI) and automatic target recognition (ATR) |
| 2.2.2. | Novel radar algorithms and architectures |
| 2.2.3. | Air defence radar systems |
| 2.2.4. | SAR/MTI systems |
| **2.3. SENSORS AND OPTRONIC SYSTEMS** | |
| 2.3.1. | EO/IR (electro-optical/infrared) detector-based systems |
| 2.3.2. | Night vision systems (NVS) |
| 2.3.3. | Laser-based systems for telemetry, LIDAR, guidance and target designation |

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| **2.4. ACOUSTIC SENSORS** | |
| 2.4.1. | Underwater acoustic sensors |
| 2.4.2. | Atmospheric acoustic sensors |
| **2.5. SENSOR DATA PROCESSING** | |
| 2.5.1. | Sensor fusion |
| 2.5.2. | Automatic and intelligent analysis of large volumes of sensor data |
| 2.5.3. | Sensor data processing for the development of active protection systems |
| **2.6. OPTRONIC COUNTERMEASURES** | |
| 2.6.1. | Active DIRCM protection on air platforms |
| 2.6.2. | Pyrotechnic decoys, flares, smoke canisters |
| **2.7. ELECTRONIC WARFARE** | |
| 2.7.1. | Non-communications electronic warfare systems |
| 2.7.2. | Communications electronic warfare systems |
| 2.7.3. | Multi-platform and cooperative electronic warfare |
| 2.7.4. | Frequency jamming counter RC-IED |

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| **3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS** | |
| **3.1. LIFE-CYCLE** | |
| 3.1.1. | Platform maintenance |
| 3.1.2. | Data intelligence applied to predictive maintenance of platforms |
| 3.1.3. | Simulation to support platform life-cycle |
| 3.1.4. | Protection against corrosion and degradation processes |
| **3.2. MATERIALS** | |
| 3.2.1. | Platform weight reduction |
| 3.2.2. | Passive platform protection systems |
| 3.2.3. | Platform signature reduction through materials |
| 3.2.4. | Materials for high temperature applications |
| **3.3. ENERGY** | |
| 3.3.1. | High-power energy systems |
| 3.3.2. | Energy harvesting systems |
| 3.3.3. | Fuel cell systems for use in the military environment |
| 3.3.4. | Systems for the microgeneration of electric power, such as microturbines or portable generator sets |
| 3.3.5. | Electric power storage systems for use in military environments |
| **3.4. LOGISTICS** | |
| 3.4.1. | Water management systems |
| 3.4.2. | Waste management systems |
| 3.4.3. | Certified non-oil-based fuels |
| 3.4.4. | Non-SFC alternative fuels |

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| **4. BASES AND INSTALLATIONS** | |
| **4.1. PROTECTION OF BASES AND INSTALLATIONS** | |
| 4.1.1. | Sensor networks for the protection of land-based installations and deployments |
| 4.1.2. | Sensor networks for the protection of maritime areas |
| 4.1.3. | Protection against explosive-based threats to infrastructures |
| **4.2. POWER AT BASES AND INSTALLATIONS** | |
| 4.2.1. | Integrated renewable electric power generation systems for bases in the area of operations |
| 4.2.2. | Smart electricity grids for defence |
| 4.2.3. | Self-production of fuels |
| 4.2.4. | Integrated and efficient air conditioning and DHW |
| **4.3. MODERNISATION OF BASES AND INSTALLATIONS** | |
| 4.3.1. | Incorporation of 4.0 technologies in the Department's bases and installations and processes |
| 4.3.2. | Smart and efficient buildings for bases and camps |

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| **5. LAND PLATFORMS** | |
| **5.1. DESIGN AND MOBILITY OF LAND PLATFORMS** | |
| 5.1.1. | Design of new generation land platforms |
| 5.1.2. | Advanced mobility systems |
| 5.1.3. | Hybrid and electric propulsion, electrification of land platforms |
| 5.1.4. | Conventional propulsion and transmission systems |
| **5.2. INTEGRATED SYSTEMS** | |
| 5.2.1. | Architecture and integration on land platforms |
| 5.2.2. | Platform crew situational awareness |
| 5.2.3. | Active and reactive protection systems |
| **5.3. LAND ROBOTICS** | |
| 5.3.1. | Conversion of platforms or groups of platforms into unmanned systems |
| 5.3.2. | Advanced functionalities in UGV based on robotic autonomy |
| 5.3.3. | Robotics for specific defence missions |

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| **6. NAVAL PLATFORMS** | |
| **6.1. NAVAL PLATFORM DESIGN** | |
| 6.1.1. | Surface naval platform design |
| 6.1.2. | Underwater naval platform design |
| 6.1.3. | Surface and underwater naval platform invisibility |
| 6.1.4. | Safety on board platforms |
| **6.2. NAVAL CONTROL, POWER AND PROPULSION** | |
| 6.2.1. | Naval platform propulsion systems |
| 6.2.2. | Naval platform manoeuvrability |
| 6.2.3. | Electric power generation systems on naval platforms |

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| **6.3.** | **INTEGRATED SYSTEMS ON NAVAL PLATFORMS** |
| 6.3.1. | Evolution of naval platform combat systems |
| 6.3.2. | Integration of unmanned vehicles on surface platforms |
| 6.3.3. | Maritime environment knowledge support system |
| **6.4.** | **UNMANNED NAVAL VEHICLES** |
| 6.4.1. | Technologies and systems aimed at unmanned underwater vehicles |
| 6.4.2. | Technologies and systems aimed at unmanned surface vehicles |
| 6.4.3. | Remotely manned naval vehicle swarms |

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| **7.** | **AIR PLATFORMS** |
| **7.1.** | **DESIGN OF AIR PLATFORMS** |
| 7.1.1. | Development of new generation manned air platforms |
| 7.1.2. | Development of rotary wing platforms |
| **7.2.** | **POWER AND PROPULSION** |
| 7.2.1. | Application of advanced electric power plant and electronic management of platform systems and status |
| 7.2.2. | Improved propulsion and power systems on air platforms |
| **7.3.** | **AVIONICS/C4I FOR AIRBORNE SYSTEMS** |
| 7.3.1. | Integrated avionics systems |
| 7.3.2. | Airborne mission systems |
| 7.3.3. | Aeronautical system-of-systems including the swarm concept |
| 7.3.4. | Alternative navigation systems to GNSS signals |
| 7.3.5. | Manned, unmanned air traffic management systems and integration of RPAS in non segregated airspace |
| **7.4.** | **RPAS** |
| 7.4.1. | Class II and III RPAS |
| 7.4.2. | Class I RPAS |

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| **8.** | **SPACE SYSTEMS** |
| **8.1.** | **SPACE SEGMENT** |
| 8.1.1. | Devices and systems making up the satellite structure |
| 8.1.2. | On-board satellite technologies for SATCOM |
| 8.1.3. | On-board satellite technologies for SEOT |
| 8.1.4. | High-altitude pseudo-satellites |
| 8.1.5. | Small satellites |
| **8.2.** | **GROUND SEGMENT** |
| 8.2.1. | Ground stations for SEOT |
| 8.2.2. | Ground stations for SATCOM systems |
| 8.2.3. | SST or SSA systems for surveillance and tracking of space debris |

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| **8.3. USER SEGMENT** | |
| 8.3.1. GNSS receivers | |
| 8.3.2. SATCOM user terminals | |
| **8.4. COMPLEMENTARY SYSTEMS** | |
| 8.4.1. Small satellite launchers | |

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| **9. SOLDIER** | |
| **9.1. SOLDIER SYSTEM** | |
| 9.1.1. Passive soldier protection systems | |
| 9.1.2. Soldier signature reduction systems through materials | |
| 9.1.3. Soldier energy systems | |
| 9.1.4. Improved soldier comfort | |
| 9.1.5. Reduction of the soldier's load/exoskeletons | |
| 9.1.6. Soldier sensorisation, computing and connectivity | |
| 9.1.7. Soldier navigation capabilities in the absence of GNSS | |
| **9.2. HUMAN FACTORS** | |
| 9.2.1. Monitoring and improvement of the soldier's performance | |
| 9.2.2. Advanced human-machine interfaces | |
| 9.2.3. Integration of people on platforms | |
| 9.2.4. Human-unmanned system interaction in missions | |
| **9.3. HEALTH ISSUES** | |
| 9.3.1. Early medical response | |

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| **10. CBRNe** | |
| **10.1. C-IED TECHNOLOGIES** | |
| 10.1.1. Remote sensing of explosive ordnance and substances in land-based environments | |
| 10.1.2. Remote sensing of explosive atmospheres | |
| 10.1.3. Advanced forensic analysis techniques | |
| 10.1.4. Detection and neutralisation of explosive-based threats in maritime environments | |
| 10.1.5. Protection against small RPAS-type threats | |
| 10.1.6. Exploitation of information to combat networks responsible for IED threats | |
| **10.2. CBRN DEFENCE** | |
| 10.2.1. Remote or stand-off CBRN detection | |
| 10.2.2. Point CBRN detection and identification | |
| 10.2.3. CBRN decontamination | |
| 10.2.4. Smart CBRN personal protective equipment | |
| 10.2.5. Collective CBRN protection | |
| 10.2.6. Medical countermeasures against CBRN agents | |
| 10.2.7. CBRN situational awareness | |

| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES |
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| **11.1. C4I INFORMATION SYSTEMS** |
| 11.1.1. Advanced C2 systems functionalities for planning and conducting military operations |
| 11.1.2. C4I systems interoperability |
| 11.1.3. Open-source intelligent analysis for defence purposes |
| 11.1.4. Intelligent exploitation of multiple information sources |
| **11.2. TACTICAL COMMUNICATION** |
| 11.2.1. Software-defined radio and cognitive radio |
| 11.2.2. Digital tactical links communications and their integration into platforms |
| 11.2.3. Connectivity and computing architectures |
| 11.2.4. New generation mobile networks |
| 11.2.5. Acoustic and optical communication in the underwater environment |
| 11.2.6. Optical communication in free space |
| **11.3. SIMULATION** |
| 11.3.1. Advanced training through simulation |
| 11.3.2. Interoperability between simulators |
| 11.3.3. Simulation as a decision-making tool |
| **11.4. INFORMATION AND SYSTEMS SECURITY** |
| 11.4.1. Automation of actions against cyber-attacks |
| 11.4.2. Cyber intelligence for predictive analysis of vulnerabilities |
| 11.4.3. Technologies in support of cyber operations |
| 11.4.4. Software and hardware cryptological devices to increase communication security |
| 11.4.5. Development of secure interconnection capabilities of multi-level systems |
| **11.5. APPLICATION OF ICT ADVANCES TO DEFENCE** |
| 11.5.1. Advances to mitigate risks and limitations in the use of AI in defence |
| 11.5.2. Applications of biometric technologies |
| 11.5.3. Applications of speech and text analysis technologies |

Table 5. Complete list of RDI lines.

# Relationship between the ETID and the EID

| | A) Command, control, communications, computers and intelligence (C4I) | B) Cyber defence | C) Intelligence, surveillance, target acquisition and reconnaissance (ISTAR) | D) Traffic control and navigation aids | E) Critical systems on board platforms | F) Space, data processing and mission systems | G) Simulation | H) Navigation, guidance control and payload systems on missiles and complex munitions | I) Complex systems integrated by other advanced weapon systems |
|---|---|---|---|---|---|---|---|---|---|
| **1. WEAPONS AND AMMUNITION** | | | | | | | | | |
| 1.1. Weapons and ammunition technologies | | | | | | | | ■ | |
| 1.2. Weapons integration and interoperability technologies | | | | | ■ | | | | ■ |
| 1.3. Application and technology-specific weapons | | | | | | | | ■ | |
| 1.4. Weapons and ammunition life-cycle support technologies | | | | | | | | ■ | |
| **2. SENSORS AND ELECTRONIC SYSTEMS** | | | | | | | | | |
| 2.1. Electronic technologies | | | ■ | | | ■ | | | |
| 2.2. Radar | | | ■ | | | | | | |
| 2.3. Sensors and optronic systems | | | ■ | | ■ | | | ■ | |
| 2.4. Acoustic sensors | | | ■ | | | | | | |
| 2.5. Sensor data processing | ■ | | ■ | | ■ | ■ | | | |
| 2.6. Optronic countermeasures | | ■ | | | | | | | ■ |
| 2.7. Electronic warfare | | ■ | | | | | | | |
| **3. COMMON TECHNOLOGIES FOR BASES AND INSTALLATIONS, PLATFORMS AND SOLDIERS** | | | | | | | | | |
| 3.1. Life-cycle | | | | | ■ | | ■ | | ■ |
| 3.2. Materials | | | | | ■ | | | | ■ |
| 3.3. Energy | | | | | ■ | | | | |
| 3.4. Logistics | | | | | ■ | | | | |

| | A) Command, control, communications, computers and intelligence (C4I) | B) Cyber defence | C) Intelligence, surveillance, target acquisition and reconnaissance (ISTAR) | D) Traffic control and navigation aids | E) Critical systems on board platforms | F) Space, data processing and mission systems | G) Simulation | H) Navigation, guidance control and payload systems on missiles and complex munitions | I) Complex systems integrated by other advanced weapon systems |
|---|---|---|---|---|---|---|---|---|---|
| **4. BASES AND INSTALLATIONS** | | | | | | | | | |
| 4.1. Protection of bases and installations | | | ■ | | | | | | |
| 4.2. Power at bases and installations | | ■ | | | | | | | |
| 4.3. Modernisation of bases and installations | | | | | | | ■ | | |
| **5. LAND PLATFORMS** | | | | | | | | | |
| 5.1. Design and mobility of land platforms | | | | | ■ | | | | |
| 5.2. Integrated systems | | | ■ | | ■ | | | | ■ |
| 5.3. Land robotics | | | | | ■ | | | | ■ |
| **6. NAVAL PLATFORMS** | | | | | | | | | |
| 6.1. Naval platform design | | | | | ■ | | | | ■ |
| 6.2. Naval control, power and propulsion | | | | | ■ | | | | |
| 6.3. Integrated systems on naval platforms | | | | | ■ | | | | |
| 6.4. Unmanned naval vehicles | | | | | ■ | | | | ■ |
| **7. AIR PLATFORMS** | | | | | | | | | |
| 7.1. Design of air platforms | | | | | ■ | | | | ■ |
| 7.2. Power and propulsion | | | | | ■ | | | | |
| 7.3. Avionics/C4I for airborne systems | | | | ■ | ■ | | | | |
| 7.4. RPAS | | | | | ■ | | | | |
| **8. SPACE SYSTEMS** | | | | | | | | | |
| 8.1. Space segment | ■ | | ■ | | ■ | ■ | | | |
| 8.2. Ground segment | ■ | | ■ | | ■ | ■ | | | |
| 8.3. User segment | ■ | | ■ | ■ | ■ | ■ | | | |
| 8.4. Complementary systems | | | | | ■ | | | | |

| | A) Command, control, communications, computers and intelligence (C4I) | B) Cyber defence | C) Intelligence, surveillance, target acquisition and reconnaissance (ISTAR) | D) Traffic control and navigation aids | E) Critical systems on board platforms | F) Space, data processing and mission systems | G) Simulation | H) Navigation, guidance control and payload systems on missiles and complex munitions | I) Complex systems integrated by other advanced weapon systems |
|---|---|---|---|---|---|---|---|---|---|
| 9. SOLDIER | | | | | | | | | |
| 9.1. Soldier system | | | | | | | | | |
| 9.2. Human factors | | | | | | | | | |
| 9.3. Health issues | | | | | | | | | |
| 10. CBRNe | | | | | | | | | |
| 10.1. C-IED technologies | | | | | | | | | |
| 10.2. CBRN defence | | | | | | | | | |
| 11. INFORMATION, COMMUNICATION AND SIMULATION TECHNOLOGIES | | | | | | | | | |
| 11.1. C4I information systems | | | | | | | | | |
| 11.2. Tactical communication | | | | | | | | | |
| 11.3. Simulation | | | | | | | | | |
| 11.4. Information and systems security | | | | | | | | | |
| 11.5. Application of ICT advances to defence | | | | | | | | | |

Table 6. Traceability of ETID sub-areas to areas of knowledge affecting essential defence and security interests

# Relationship between the ETID and the strategic RDI lines of the ECCTI 2021-2027

| | 1. Weapons and ammunition | 2. Sensors and electronic systems | 3. Common technologies for bases and installations, platforms and soldiers | 4. Bases and installations | 5. Land platforms | 6. Naval platforms | 7. Air platforms | 8. Space systems | 9. Soldier | 10. CBRNe | 11. Information, communication and simulation tecnologies |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **HEALTH** | | | | | | | | | | | |
| Precision medicine | | | | | | | | | ■ | | |
| Infectious diseases | | | | | | | | | | ■ | |
| New diagnostic and therapeutic techniques | | | | | | | | | ■ | ■ | |
| Cancer and geroscience: ageing, degenerative diseases | | | | | | | | | | | |
| **CULTURE, CREATIVITY AND INCLUSIVE SOCIETY** | | | | | | | | | | | |
| Human evolution, anthropology and archaeology | | | | | | | | | | | |
| Cognition, linguistics and psychology | | | | | | | | | | | |
| Hispanic philology and literature | | | | | | | | | | | |
| **SECURITY FOR SOCIETY** | | | | | | | | | | | |
| Spatial dimension of inequalities, migrations and multiculturalism | | | | | | | | | | | |
| Monopolies and market power: measurement, causes and consequences | | | | | | | | | | | |
| Cyber security | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | ■ |

| | 1. Weapons and ammunition | 2. Sensors and electronic systems | 3. Common technologies for bases and installations, platforms and soldiers | 4. Bases and installations | 5. Land platforms | 6. Naval platforms | 7. Air platforms | 8. Space systems | 9. Soldier | 10. CBRNe | 11. Information, communication and simulation technologies |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Protection against new security threats | | | | | | | | | | | |
| **DIGITAL WORLD, INDUSTRY, SPACE AND DEFENCE** | | | | | | | | | | | |
| Artificial intelligence and robotics | | | | | | | | | | | |
| Photonics and electronics | | | | | | | | | | | |
| Next generation Internet | | | | | | | | | | | |
| Mathematical modelling and analysis and new mathematical solutions for science and technology | | | | | | | | | | | |
| Astronomy, astrophysics and space sciences | | | | | | | | | | | |
| Advanced materials and new manufacturing techniques | | | | | | | | | | | |
| **CLIMATE, ENERGY AND MOBILITY** | | | | | | | | | | | |
| Climate change and decarbonisation | | | | | | | | | | | |
| Sustainable mobility | | | | | | | | | | | |
| Sustainable cities and ecosystems | | | | | | | | | | | |
| **FOOD, BIOECONOMY, NATURAL RESOURCES AND THE ENVIRONMENT** | | | | | | | | | | | |
| Biodiversity exploration, analysis and foresight | | | | | | | | | | | |
| Smart and sustainable agri-food chain | | | | | | | | | | | |

Table 7. Traceability of the ETID areas with the strategic RDI lines of the EECTI 2021-2027.

# APPENDIX B. Technological objectives

This appendix describes in more detail the scope of each of the technological objectives included in the ETID, as well as the type of actions planned to be developed over the next few years in relation to each of them (see Table 8).

As explained in Chapter 3 of the Strategy, these technological objectives are organised into three levels, depending on the size and characteristics of the systems and technologies involved and the type of actions planned to achieve them (see Figure 13).

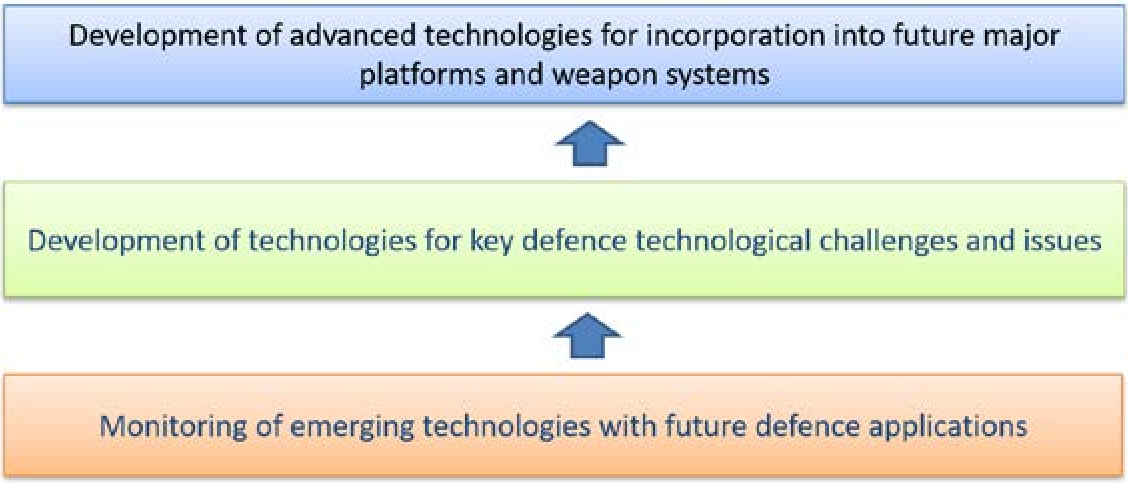



Figure 13. Technological objectives pillar actions.

While for the first and third levels (the first and last respectively) a single fact sheet has been included which summarises the scope and purpose of the technological objectives considered at each level, in the case of the intermediate level, given the greater heterogeneity of the objectives included, a separate fact sheet has been included for each of them.

The following table includes the set of technological objectives included in this appendix.

| Specific level/scope of action | Technological objectives |
|---|---|
| **Development of advanced technologies for future major platforms and weapon systems** | Technologies for the development of future major platforms and weapon systems used by the Armed Forces in the land, sea, air and space domains. |
| **Defence applications with high technological requirements** | Munitions guidance and advanced control technologies |
| | High-performance electronic technologies |
| | Electronic warfare solutions adapted to the current and future electromagnetic environment |
| | Military communications in complex environments |
| | Solutions for cyber operations |
| **Defence against asymmetric threats** | Advanced land-based IED detection systems |
| | Counter RPAS systems |
| | CBRN threat control |
| **Harnessing the civilian technology push** | AI – Automatic and intelligent analysis of large volumes of sensor data |
| | AI – Technologies for predictive maintenance of military platforms |
| | AI – Intelligent analysis of multiple sources of information for decision support |
| | Robotics – Unmanned land platforms for defence missions |
| | Robotics – Unmanned surface and underwater vehicles for defence missions |
| | Robotics – Innovative applications of RPAS in defence |
| | Materials – Passive platform and soldier protection |
| | Materials – Reduction of platform and soldier signatures |
| | Space – Use of small satellites and pseudo-satellites in defence applications |
| **Enhancement of human capabilities** | Technologies for the dismounted soldier |
| | Exoskeletons for defence applications |
| | Advanced training through simulation |
| **Energy sustainability** | Power generation and energy efficiency in isolated bases and infrastructures |
| | New propulsion systems for manned and unmanned platforms |
| **Digital transformation** | 4.0 technologies for the Department's digital transformation |
| **Initial technological capability development** | Technologies for the development of high-power laser weapons |
| | Technologies for RF directed-energy weapons |
| | Energy systems for defence applications requiring high electric power pulses |
| | Detection technologies for the development of active protection systems |
| **Monitoring of emerging technologies with future defence applications** | Emerging technologies with potential future defence applications |

Table 8. Technological objectives according to specific environments

| DEVELOPMENT OF ADVANCED TECHNOLOGIES FOR FUTURE MAJOR PLATFORMS AND WEAPON SYSTEMS |
|---|
| **Technologies for the development of future major platforms and weapon systems used by the Armed Forces in the land, sea, air and space domains** |
| Development of advanced technologies for their incorporation into the future major platforms and weapon systems used by the Armed Forces in the land, sea, air and space domains, which are derived from the requirements included in the Military Capability Target (OCM) and the Long-Term Force Target (OFLP), the development of which acts as a driving force for the technological capability development of very broad industrial sectors, and is also a driver of quality employment in these sectors. |

Given the nature of the threats that the Armed Forces have to face, major platforms and weapon systems in the land, sea, air and space domains are necessary, incorporating highly complex technological advances, which are often carried out through international cooperation, involving significant financial investment and very long development timeframes.

As these systems are designed to be in service for decades, technological programmes must be undertaken a number of years in advance, in which the latest technologies are incorporated into the most critical functions of the system through technology demonstrators, which allow the readiness of these developments and the risk of transferring them to the end systems to be validated.

The most representative programme at present is the FCAS, understood as the next generation of air combat capabilities, which will combine manned components, remotely manned platforms, effectors and other cooperating elements integrated into a system-of-systems architecture, operating in a network as a single functional entity. Thus, the national FCAS concept envisages, fundamentally, the NGWS as the main element, together with the EF-18 MLU replacement manned aircraft and the evolution of the Eurofighter aircraft (EF long-term evolution); the NGWS programme aims to renew the current Eurofighter (Germany and Spain) and Rafale (France) fleets by around 2040. The programme is structured in a set of seven technological pillars: new-generation fighter (NGF), unmanned remote carriers (RC), new advanced sensor systems (SENSORS), combat cloud (CC), simulation (SIMLAB), propulsion (ENGINE) and low observability (ELOT).

In this same aeronautical field, there are other opportunities related to the development of future rotary wing systems, in addition to others in the land domain (technologies for future ground combat systems, Brigade 2035, for future low-level anti-aircraft defence systems, etc.), in the sea domain (technologies for future naval combat systems) and in the space domain (technologies for future satellite systems).

Within the framework of this objective, consideration is given to the projects in which Spain participates that are developed within the framework of international cooperation programmes, and the projects developed nationally that are applicable to these future major platforms or weapon systems.

| DEFENCE APPLICATIONS WITH HIGH TECHNOLOGICAL REQUIREMENTS |
|---|
| **Munitions guidance and advanced control technologies** |
| Improved munitions performance through the incorporation of guidance and navigation devices and control systems, including both actuation and control devices and C4I systems, enabling increased accuracy and advanced mission control to maximise fire support effectiveness and minimise unnecessary effects and collateral damage. |

The use of guided and smart munitions is one of the aspects gaining the most relevance and priority recently in the field of defence. Improved munitions precision through the incorporation of guidance and navigation and actuation and control systems, in addition to reducing collateral damage, reduces the logistical load, as it reduces the number of rounds required to hit a target and it is also possible to reduce the size of the warhead and enhance its effects. Likewise, the incorporation of advanced control functions through C4I opens up a range of new options such as the ability to abort the mission in flight, obtain information on the target and on the effectiveness of the mission, etc. Finally, the provision of intelligence and autonomy allows mission accomplishment in degraded environments, or real-time re-adaptation based on new information obtained after the fire action.

Implementing this set of functionalities involves a significant number of technological challenges, both in relation to the guidance and navigation technologies themselves, actuation and control, processing and learning algorithms, communications systems, etc., which make it possible to obtain highly dynamic aerial vehicles applicable to the field of munitions, as well as their adaptation to the particularities of each type of munitions and their integration into specific munitions, which is also an intensive field in terms of testing.

Over the next few years, the plan is therefore to combine actions at different levels of technology readiness and in different cooperation environments, which will require a combination of investments from within and outside the Department.

Thus, at a lower level of technology readiness, the support of R&T activities related to highly dynamic platform technologies, enabling future developments of guided munitions, is envisaged. In addition, the set of projects initiated, mainly through calls for proposals of the COINCIDENTE programme, concerning different types of guided munitions, will foreseeably require subsequent phases to increase technology readiness, to which new projects related to the needs of the Armed Forces may be added with a view to obtaining performance prototypes of high technology readiness levels. Finally, potential participation in European projects is envisaged in order to research and develop solutions for complex weapon systems incorporating guided or smart munitions that, due to their level of complexity, would be difficult to address with strictly national means.

| DEFENCE APPLICATIONS WITH HIGH TECHNOLOGICAL REQUIREMENTS |
|---|
| **High-performance electronic technologies** |
| Improve the performance of devices and components that are part of military radio frequency (RF) systems by employing technologies and developments applicable to these elements to achieve advanced functionalities in radar, electronic warfare (EW) and communications systems. |

RF systems provide essential capabilities for modern defence systems, usually with much higher technical requirements than civilian applications. Improvements in device characteristics translate directly into improved performance of entire systems, providing a technological advantage that can be decisive in the theatre of operations.

In addition, the implementation of these technologies has an important impact on the reduction of the size, weight and power consumption (SWaP) of RF systems, which is especially critical in air (mainly RPAS) and land platforms, where size, weight and power consumption play a very important role.

Within the scope of the objective, RDI activities are envisaged mainly for the development of Active Electronically Scanned Array Antennas (AESA), transmit/receive (T/R) modules, solid state amplifiers (mainly based on gallium nitride, GaN), components/subsystems based on photonics technology, as well as advanced antenna technologies (low frequency compact, conformal) and metamaterials (applied to RF components), etc., which, although currently at a fairly low level of technology readiness, will have a significant impact on military systems in the longer term.

The technological challenges for AESA antennas are related to achieving multi-beam and simultaneous capability for multiple target tracking, high beam agility (almost instantaneous) and even adaptive interference cancellation capability. The T/R modules integrated into them must be compact, high-power and high bandwidth; therefore, in the future they will probably be based on GaN amplifiers. On the other hand, RF components/subsystems based on photonics technology will have a considerable impact on the performance of the systems, by overcoming technological obstacles that have so far been limited by bandwidth, losses, size or interference of current electronic systems.

During the period of validity of the ETID, developments in the field of AESA / TR modules / GaN will coexist, mainly within the framework of the F-110 technological programmes, as well as developments of lesser readiness in GaN technology and metamaterials, in the EDA environment, with the promotion of other future developments expected in connection with the aforementioned technological challenges, combining investments from within and outside the Department to this end.

| DEFENCE APPLICATIONS WITH HIGH TECHNOLOGICAL REQUIREMENTS |
|---|
| **Electronic warfare solutions adapted to the current and future electromagnetic environment** |
| Development of state-of-the-art electronic warfare systems in the non-communications and communications bands, both electronic support measures (ESM) and electronic countermeasures (ECM), to which technological advances in antennas and RF devices, modules and antennas will be applied, as well as advanced warning and intelligence algorithms adapted to the signals present in the electromagnetic (EM) environment. |

The main objective of electronic warfare (EW) is to control the electromagnetic spectrum in order to guarantee its use for friendly forces, and to be able to deploy its full combat potential and prevent the use of the spectrum by enemy forces. If electromagnetic superiority is not available as a prior step to action, the chances of success are minimal no matter how powerful the means of manoeuvre and firepower employed. Given the growing relevance expected of this area in the coming decades, it is critical to keep the EW and self-protection systems of all platforms used in defence up to date and ensure the national autonomy.

Since the evolution of the threat is becoming increasingly complex, the trend points towards EW systems for both non-communications and communications, with shared frequency bands, resulting in technological challenges related to shared apertures between different RF systems and their adaptation to the platforms, leading to the onset of multifunctional systems. The specific functions and characteristics of non-communications and communications systems also mean that each one has specific and different technological challenges. It is also worth noting that the application of artificial intelligence (RF machine learning) in future developments should play an important role in the coming years to give rise to cognitive EW.

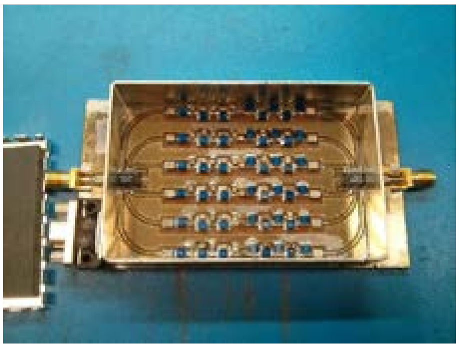
In particular, in the case of air platforms, it is important to promote the modularity of the systems through the development of PODs, for both ESM and ECM, which avoid the use of dedicated platforms.

The development of this objective will benefit from the progress achieved at the component or subsystem level in the “High-performance electronic technologies” objective, which will enable the efforts of this objective to be geared toward achieving complete developments with medium or high levels of technology readiness.

In the coming years, the plan is to make the execution of a set of RDI projects already initiated in the three domains, land, sea and air, for manned and unmanned systems (including small-sized ones), compatible with the development of new EW systems projects to which the latest HW/SW advances will be applied to improve their performance or incorporate new capabilities.

| DEFENCE APPLICATIONS WITH HIGH TECHNOLOGICAL REQUIREMENTS |
| --- |
| **Military communications in complex environments** |
| Improve interoperability and bandwidth limitations generated by new radio transmission needs in the field of national and international operations, both in line of sight (LOS) and beyond line of sight (BLOS), as well as frequency spectrum management for radio transmission in an increasingly congested environment. |

Over the past few years, the operating environment has evolved, giving way to new types of deployed platforms and sensors (UAV, UGV, IoT, etc.), each with different transmission capabilities and requirements, which has triggered new needs for transmitting large amounts of information with low latency over short or long distances.



Similarly, military operations often take place in radio frequency-dense environments, which can lead to interference between different radio systems of allies or the possibility of denial of service by adversaries. Therefore, communications must not interfere with those of allies in joint missions, where the spectrum may become congested, and technologies are needed that can adapt to this unfavourable circumstance. The traditional spectrum licensing model will cease to be sustainable with the emergence of new nodes and technologies that make use of it; spectrum sharing will therefore have to be introduced to maximise its use.

The latest technological advances place SDR (software defined radio) as the enabling technology to solve the interoperability problems between different levels in missions and the bandwidth limitations generated by new needs, as well as the complicated coexistence of the current radios with inhibitors, thanks to the use of multi-band and multi-channel platforms.

Within the scope of this objective, actions aimed at the development of new SDR waveforms are envisaged to achieve communication ranges with greater scope and high data transmission rates. The development of cognitive radio systems will also be promoted to improve and dynamically manage the electromagnetic spectrum to increase interoperability in communications during operations with allies and to enable more effective spectrum management through the cooperative and consensual assignment of radio frequencies.

With the development of this objective, impetus will continue to be given to the investments that the Ministry of Defence has been making in RDI projects with the aim of acquiring autonomy and national sovereignty in tactical radio communications.

In the coming years, RDI activities aimed at strengthening this technological objective are expected to be implemented, combining investments from within and outside the Department through national and international cooperation, taking into account the specific requirements and needs of military applications.

| DEFENCE APPLICATIONS WITH HIGH TECHNOLOGICAL REQUIREMENTS |
|---|
| **Solutions for cyber operations** |
| Development of technological solutions to collect, analyse and visualise information on cyber threats and cyber incidents and generate intelligence to anticipate future attacks, as well as to carry out an active, balanced and proportional response to the attack received under the principle of self-defence. |

Cyber security is an implicit and enforceable military capability in any system or network for military use and operations in cyberspace are permanent, due to the very nature of the threat in this area. The Ministry of Defence needs to enhance its cyber defence capabilities in order to strengthen its resilience and its ability to operate continuously, agilely and effectively in an increasingly demanding scenario such as cyberspace. It also needs to be able to evolve and adapt at the same pace as the technologies and threats themselves, in keeping with legality and legitimacy and in constant collaboration with other civilian and military actors.

This technological objective focuses on the development of new technological solutions that help to generate a cyber intelligence that ensures the freedom of action of its own forces in cyberspace and enables the limitation of this same freedom of action where the adversary is concerned, as a proportional and balanced response to an attack received.

Among other purposes, the idea is to use past experience and present information to anticipate what might happen in the future, trying to predict the effects and mitigating or completely avoiding them before they occur, taking a proactive stance on the actions to be taken. It is also an intelligence that provides superiority, not only in cyberspace but extending to all other physical (land, sea, air, space) and cognitive domains.

However, the availability of such intelligence gives rise to numerous technological challenges. It involves obtaining, analysing and correlating data from multiple networks in cyberspace in order to answer complex questions (e.g., who can attack and when, what techniques and procedures they use, where they launch attacks from, who they target first, how sophisticated they are, what the history of similar attacks is, etc.). In turn, showing the commander of an operation how threats from cyberspace can affect physical domains is a challenging rather than a trivial task. While there are commercial tools that can help, specific RDI actions are needed to address these challenges.

In the coming years, it is planned to promote or support the development of RDI activities that will give impetus to the generation of cyber intelligence through the analysis of available information and enable enemy attacks in cyberspace to be countered or responded to.

| DEFENCE AGAINST ASYMMETRIC THREATS |
| --- |
| **Advanced land-based IED detection systems** |
| Development of technologies for remote detection systems for improvised explosive devices (IEDs), enabling operational performance for the protection of military units against asymmetric warfare. |

The capability to detect IEDs, i.e., devices placed or made in an improvised manner incorporating destructive, lethal, pyrotechnic or incendiary material, is of vital importance for the protection of the Force and the civilian population in hybrid warfare scenarios. If the appropriate detection capability is available, it will be possible to identify, avoid, neutralise or mitigate the threat, and to obtain information that will enable the adversary to be identified, pursued and defeated.

While explosive detection is a threat addressed in the security field, there are several scenarios of special interest in defence, among which route clearance stands out, not only against IEDs, but also against conventional landmines and unexploded ordnance (UXO). Route clearance uses increasingly complex multi-sensor detection systems with data processing and fusion to provide greater reliability. In addition to hand-held detectors, there is a need to develop detectors that can be integrated into moving military vehicles, especially on robotic land or air platforms, which can detect traces and confirm the presence of an IED remotely, minimising the risk to operating personnel. These detectors must therefore be lightweight, compatible with the payload capacities of the platforms and remotely used.

There are many technological challenges associated with the detection of an IED, which is usually buried or camouflaged by natural or artificial elements. In general, the aim is to detect the system or elements of the system (switch, power source, initiator, main charge and container), traces of the explosive material or any other element or condition in the environment that raises suspicion of the presence of an IED (changes in terrain density, earth movements, etc.).

Thus, there are direct detection technologies, which either try to detect the device or the explosive substance contained in considerable quantity (bulk detection) or the vapour emissions of the explosive or solid or liquid residues of the explosive at trace level (trace detection). In addition, there are other indirect detection methods based on discovering any other element, trace or indication of the presence of an IED, such as metallic elements, anomalies in terrain density or earth movements.

During the period of validity of the ETID, the implementation of RDI activities aimed at boosting this technological capability is envisaged, combining investments from within and outside the Department through national and international cooperation. Specifically, the plan is to combine actions to consolidate activities already initiated to bring the solutions under development closer to the operating environment, with support for new RDI projects, particularly those focused on the hybridisation of detection methods and technologies, with actions to evaluate existing technological demonstrators and prototypes under realistic conditions, providing the demonstrators with technical criteria.

| DEFENCE AGAINST ASYMMETRIC THREATS |
|---|
| **Counter RPAS systems** |
| Development and adaptation to military requirements of counter RPAS systems capable of detecting, identifying and neutralising RPAS used against installations, vehicles, and people, for use both in areas of operation and in national territory. |

The improved performance of smaller RPAS and their lower cost has enabled access to the general public, in some cases causing incidents when such systems invade protected spaces or are exploited by terrorist groups that use them for surveillance activities or to carry out attacks. These types of threats have been reinforced by technological progress and innovation, and it is foreseeable that they will also evolve in terms of sophistication and complexity in the coming years.

Aspects such as the size reduction of RPAS, their increasing energy autonomy, the improvement of communication links and the use of new frequencies, lower dependence on navigation and command and control systems, the use of more dangerous payloads, swarming, etc. will significantly complicate the detection, identification and neutralisation capabilities of these systems, making it necessary to develop RDI activities to improve the performance of current counter RPAS systems.


Actions are therefore required to improve the capabilities for the detection, tracking and identification of small targets in complex environments, adapted to the maximum number of scenarios, based mainly on the combined use of different types of sensors and the development of new advanced signal processing and fusion algorithms that minimise the number of false positives. In addition, neutralisation solutions adapted to different scenarios are required to minimise the possibility of collateral damage. It is also necessary to advance in the modularity of solutions both at hardware and software level, so that they can be updated, integrate new functionalities and adapt to new requirements in a simple, flexible and affordable way.

These are systems with very important potential for dual use, given the similarities between the needs of the Armed Forces and the Defence and Security Forces, which favour the combination of investments from within and outside the Ministry of Defence to make progress where this objective is concerned.

In the coming years, the idea is to combine actions at different levels of technology readiness and in different cooperation environments. In particular, it is planned to continue with the technical-operational evaluation of existing technological solutions, extending the evaluation of portable systems to fixed systems, as well as to technologies that will enable the capabilities of counter RPAS systems to be expanded in accordance with defence needs. It is also planned to promote and support technological development projects to improve the capabilities of current systems in relation to their use for defence purposes. Finally, there is interest in making progress on the development of technical validation capabilities for counter RPAS systems in conditions representative of current and future threats with a view to establishing our own evaluation framework.

| DEFENCE AGAINST ASYMMETRIC THREATS |
| --- |
| **CBRN threat control** |
| Development of CBRN detection, identification and monitoring (DIM), protection and decontamination technologies to prevent or solve CBRN crisis situations quickly and effectively, minimising the impact on personnel and the environment. |

The current capability to preserve a given area from CBRN threats or to act in a crisis situation has certain limitations. CBRN detection technologies in the field are far from being able to perform effective DIM activities for early warning. Moreover, current decontamination systems are based on the use of large volumes of corrosive liquids that are harmful to humans, the environment and electronic equipment, and also entail a large operational logistical load. In addition, it is necessary to strengthen the protection capability of our Armed Forces, both individual (PPE) and collective, mainly against epidemiological agents.

Advances in sensoring technologies enable the development of devices of very small size and weight which, combined with communications technologies and in some cases artificial intelligence, make it possible to obtain very high-performance remote sensing systems necessary for the detection and identification of CBRN atmospheres. At national level, there is capacity for the development of some of these technologies, such as sensors based on specific semiconductors or CdZnTe, surface plasmon resonance, laser-based technologies, optical detectors, quantum dots, metalorganic networks, biosensors based on DNA sequencing, among others.

Similarly, smart CBRN decontamination technologies are being developed that avoid or greatly reduce the use of liquids. These are very new technologies that could completely change the way of dealing with a contaminated scenario, such as cold plasma generation, cloud abatement mist generation, catalytic materials or supercritical fluids.

Regarding the development of advanced PPE, the aim is to integrate new sensorisation technologies into the NBC suit or filters to detect the presence of agents or the exhaustion of adsorbent material, either in the suit or in the respiratory protection equipment. Also, the incorporation of self-decontaminating materials would provide greater protection and prevent the PPE exposed to the threat from becoming a secondary source of contamination.

During the period of validity of the ETID, it is planned to promote or support RDI activities relating to the aforementioned challenges. Given the dual interest of these technologies, it is foreseen to support the R&T of this objective through national programmes with external funding, as well as through international cooperation. The contribution of the Ministry of Defence will be mainly geared toward the adaptation of the technologies to the military environment and to test and trial activities in exercises at national level or through international collaboration, where real CBR agents can be used, in order to achieve TRL 8-9.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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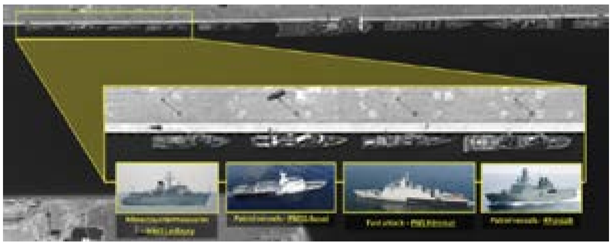
| **AI – Automatic and intelligent analysis of large volumes of sensor data** |
| Development of algorithms capable of automatically detecting, recognising or identifying the presence of significative and interesting entities to the Armed Forces in the data provided by sensors used in defence, in order to reduce the analysis load for human operators. The interest is specifically geared toward the application of the latest advances in artificial intelligence (AI) to exploit the data provided by sensors used in highly complex scenes, where until now there were no solvent alternatives to automate these analyses. |



The past few years have seen tremendous growth in the ability of the Armed Forces to acquire huge amounts of data from all types of deployed sensors (on board all types of land, naval, air and space platforms or in fixed locations) and to exchange them with other systems through networks and communication links. However, it is still very difficult to automatically extract the information of interest included in these data; in many cases a human operator must therefore perform this task, which constitutes a bottleneck of growing importance, limiting the possibilities for the use of sensory information by the Armed Forces.

In parallel to this, in the field of AI there have been very significant advances in the development and use of new techniques and algorithms, which have made it possible to tackle hitherto unfeasible problems. These are solutions that, starting from large amounts of data, previously tagged with the user's knowledge, are able to analyse very specific problems, usually related to the identification of the presence of various types of entities on the scene and their classification according to various categories (presence of vehicles, people, vessels, installations, etc.). Such algorithms are still far from providing the general intelligence that a human is capable of, but this is a step forward that may lay the groundwork for more complex analysis in the future.

Given that the scope of the objective includes all types of sensors for multiple applications, initially the actions will focus on those that provide information on highly complex scenes, where until now there were no solvent alternatives to automate the analysis, and for which there is a sufficient amount of tagged data to start the training of the algorithms. The automatic analysis of sensor data for the guidance and navigation of remotely piloted platforms is excluded from this objective, as it is included in its specific objectives.

In the coming years, it is expected that it will be possible to carry out a series of RDI projects, representative of different military missions, which will make it possible to understand the potential and limitations of these new technologies and lay the foundations for a more extensive use in defence, in addition to clarifying how to support the life-cycle of this type of AI-based systems. At the same time, it is planned to promote the implementation of data collection/tagging activities in those applications that are not ready for this, enabling future data analysis. The possibility of partially promoting these developments with funding from outside the Ministry of Defence is envisaged.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **AI – Technologies for predictive maintenance of military platforms** |
| Development of technologies that can be integrated into the platforms themselves in relation to the concepts of predictive maintenance aimed at forecasting malfunctions and optimising the maintenance of military platforms (sensorisation, data generation, malfunction analysis, etc.) and valid applications for data management using methods based on Big Data, IoT, Artificial Intelligence and analytical visualisation. |

The need to extend the operational life of platforms to save costs and increase their availability requires the development of solutions that ensure their proper functioning and performance from the moment they are put into service and throughout their operational life. This requires effective and efficient life-cycle support, since with use and time, the natural tendency is for the performance and capabilities of platforms to become reduced, both through natural degradation due to use, and technological obsolescence.

Currently, maintenance technologies are more focused on scheduled or preventive maintenance tasks. Platforms regularly undergo the overhauls recommended by manufacturers, who are generally very conservative and may carry out unnecessary part replacement. The incorporation of new technologies in platform maintenance tasks could change this trend toward predictive maintenance, detecting in advance potential malfunctions of military platform components in the three domains: land, sea and air. This would represent a significant advance in the logistics management of the Armed Forces, while reducing the number of outages and increasing the availability of military systems.

The main technological challenges involve achieving the correct sensorisation of the parts of the platforms most susceptible to malfunctions or of those elements considered critical for the correct operation of the system. Other main challenges concern the collection, management and adequacy of the large volumes of data generated by the different platforms as well as the development of the set of intelligent algorithms for the automatic analysis of these data, so that they are effectively capable of accurately and reliably predicting the remaining useful life of each component or system.

In the coming years, a set of RDI projects already underway, aimed at platforms in the three domains, will coexist with other future developments that are expected to be promoted or supported, which will continue with these efforts or address other types of platforms not yet included. To this end, combining the Ministry of Defence's investments with other external sources of funding is envisaged.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **AI – Intelligent analysis of multiple sources of information for decision support** |
| Development of technological solutions that, taking advantage of the latest advances in AI, Big Data and data analytics technologies, enable the effective and efficient analysis of multiple data sources from the entire information spectrum, including open sources, in order to help analysts create intelligence that supports decision-making in different domains of interest to defence. |

The increasing amount of data sources from sensors or open sources, combined with the rapid emergence and evolution of new threats for defence and the need to accelerate decision-making cycles, requires advanced tools to automatically and intelligently analyse this enormous amount of data, so that usable information can be obtained for decision-making.

Although important steps have been taken in recent years to integrate multiple data sources for analysis, progress is still necessary in some areas. On the one hand, capabilities are needed to process the enormous volume of data from open sources to obtain high-value intelligence to provide situational awareness, predict and detect threats, detect patterns, behavioural anomalies and demographic, economic, social, political and religious contextualisation during operations. This is also a need that is becoming increasingly important given the predominant role that the cognitive domain is acquiring as a permanent confrontational environment, in which social media act as a vehicle for instant communication. On the other hand, there is a need to develop tools capable of analysing the entire set of available data automatically, establishing new interrelationships between isolated data and adding context information in the analyses to infer high-value meaning for decision-making.

The great advances in AI, Big Data and data analytics technologies that have been taking place in the civil sector can provide the basic technological support by facilitating the collection, storage and representation of these huge amounts of data. However, there are many existing technological challenges that limit the possibilities of the Armed Forces to make use of all of these data sources in accordance with their needs.

Specifically, aspects such as the enormous volume of data to be processed; the definition of exhaustive, complete and adequate taxonomies and ontologies for each particular problem, which limit the search range to a finite set of sources and support the decision-making process; the multiplicity of languages and formats of the information (video, image, audio, etc.); the vague nature of the natural language; the absence of geolocation for some of these sources; the veracity of the information; the need to propagate uncertainties as correlation and fusion processes progress; the multiple algorithmic approaches that can be used in each particular problem; the need to combine open data sources with proprietary and even classified data sources; and the need to explain decisions in the face of the opacity of some AI-based algorithms are just some of these challenges. In addition, the analysis must be structured around the identification by the end user of the specific problem to be solved and the specification of the most relevant variables, which often requires answers to relatively abstract or ambiguous questions.

To address these challenges, in the coming years it is planned to carry out a series of RDI projects representing the different cases of use that are of interest to defence, which will allow us to understand the potential and limitations of the existing technology while addressing more complex problems. Collaboration with other funding agencies at the national level is envisaged to address projects in this field that have greater dual use.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **Robotics – Unmanned land platforms for defence missions** |
| Development of new land-based robotic systems to carry out missions in unmanned mode, providing them with specific functionalities according to the particularities of the mission and the desired level of autonomy, with a view to minimising the exposure of personnel to the risks present in the operational scenarios and freeing them from monotonous or physically and mentally demanding tasks. |

In recent years, there have been enormous advances in the fields of robotics and artificial intelligence, which has enabled the development and proliferation of numerous robots with increasing levels of decision-making autonomy. The possibility of taking advantage of these civilian advances and transferring them to the military field would make it possible to obtain robotic systems for carrying out missions in unmanned mode, with the consequent advantages that this would entail, fundamentally related to the elimination of risk for the personnel involved in the mission, as well as the reduction of their physical load and the increase in operational efficiency, in specific cases.

The military application of civilian developments is not immediate, as there is a set of conditioning factors related to the operating environments and mission characteristics that considerably increases the complexity of the problem (unstructured driving environments, possible absence of GNSS signal, security and robustness of communications, potential presence of other allied, neutral or enemy units, etc.), which means that this adaptation must be very progressive.

The main technological challenges in this field include, on the one hand, the development of a set of technical functionalities that enable both the conversion of manned military vehicles into unmanned ones, and the provision of advanced autonomous functionalities to one or several platforms (either in-service vehicles that have been robotised or smaller robots), so that they can be guided and operate in unstructured environments with greater autonomy. On the other hand, these challenges also relate to the adaptation of existing robotic platforms to the specific requirements of different military missions, including payloads. Of particular relevance in this adaptation are the following missions: C-IED/CBRN, surveillance and reconnaissance, combat, soldier logistics support, search and rescue, engineering, medical evacuation, operations in urban environments and emergency response.

During the period of validity of the ETID, developments already underway (e.g., the automation of a convoy of vehicles or the adaptation of an automated military vehicle to defence requirements) will coexist with technical-operational validation tests on existing demonstrators or prototypes in realistic environments, as well as with other future developments aimed at addressing the aforementioned technological challenges. The highly dual nature of the technologies involved means that funding from outside the Department is envisaged to carry out part of these developments.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **Robotics – Unmanned surface and underwater vehicles for defence missions** |
| Design and development of unmanned offshore platforms, both surface and underwater, autonomous or remotely operated systems (UMS), as well as the integration of sensors, systems and equipment to provide them with the capabilities required by the Armed Forces. |

Technological progress in robotics in recent years has led to a significant evolution of naval vehicles and robots, which are becoming increasingly indispensable in both civilian (identification of marine species, hydrological analysis, firefighting measures, etc.) and military (surveillance, detection and neutralisation of artefacts, etc.) applications.

The use of this type of systems in defence provides numerous advantages in the support of Navy ships, which will be able to improve their ability to detect and neutralise the threat (mine action) or their REA (rapid environmental assessment) capability, reducing the necessary effort and minimising the risk to personnel and material. It also offers advantages in the reduction of costs relating to the acquisition of larger manned vessels, the crew of these vessels, and the minimisation of errors caused by fatigue or stress.

The main technological challenges in this area concern the design of the unmanned platform (both underwater and surface), as well as to the improvement of its payload, its actuation and control systems, propulsion and on-board power generation, manoeuvrability and communications systems with the platform or main control station. In addition, autonomy will be introduced, both for navigation and for carrying out specific missions. Furthermore, the creation of swarms of such platforms, as well as collaborative systems with air platforms, sonobuoys or static underwater buoys, makes it necessary to advance in aspects of course planning, mission synchronisation and interoperability. Finally, other aspects such as the development of automated launching and recovery mechanisms for these vehicles from their base platform, or their operational regulation, may facilitate their extensive use in defence.

In the coming years, the technological development projects currently underway, both on surface and underwater platforms, will coexist with the technical-operational validation campaigns of demonstrators and prototypes developed by the national technological and industrial base, within the framework of the BARRACUDA programme. In turn, it is planned to promote or support the development of other future projects aimed at addressing the aforementioned technological challenges.

The high dual use of these platforms means that a significant part of progress will be made on the basis of funding sources external to the Ministry of Defence. The Department's investment efforts will be therefore focus mainly on testing, on providing technical criteria for developments and on technological developments that affect aspects exclusive to the defence use of these types of systems.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| Robotics – Innovative applications of RPAS in defence |
| Development and adaptation to military requirements of existing RPAS in order to enable new innovative ways of approaching defence missions, expanding current operational possibilities. |

In recent years, the development of remotely piloted aircraft systems (RPAS) has been notable in both the civilian and military spheres, where their use is being extended to different units of the Armed Forces. The obstacles encountered in developing technology that can be installed on board these platforms are relatively few, compared to those of the aeronautical sector. This opens up interesting possibilities for defence, by taking advantage of the significant civil sector push.

However, given the variety of missions to be carried out by the Armed Forces and the continuous advances and innovations in on-board RPAS technologies, there are many operational possibilities that have yet to be developed.

In order to achieve a more extensive use of these types of systems in defence, there are still many technological challenges that need to be addressed, given the demanding operational requirements of the current scenarios. These challenges concern aspects such as the limitations in terms of energy autonomy of the platforms, especially those with electric propulsion; their vulnerability to communications jamming or derived from their high dependence on GNSS signals; the capacity of their communications systems in terms of range, robustness and bandwidth; the necessary reduction in weight and size of payloads and the improvement of power management; their use in confined environments; the reduction of their signature or swarm operation, among others.

In the coming years, a series of RDI activities aimed at promoting this objective will be implemented, combining investments from within and outside the Department through national and international cooperation.

Specifically, taking advantage of the technological push that exists at civilian level, as well as the dual use of these systems, it is planned to continue with the technical-operational evaluation of demonstrators and prototypes, as well as to support developments that facilitate their adaptation and use in new defence applications.

In particular, it is planned to focus on the area of RPAS swarms, in order to facilitate the definition of requirements and their adaptation to future defence needs.

In addition, there are plans to promote and support military-specific technological developments, such as the development of loitering systems and the arming of RPAS, among others, provided that their use is carried out under human-in-the-loop control and supervision, the improvement of ISTAR capabilities and the adaptation of these platforms to EW (signals intelligence (SIGINT), communications intelligence (COMINT)) and explosive ordnance disposal (EOD) missions, among others.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **Materials – Passive platform and soldier protection** |
| Development of new materials to obtain more effective passive protection systems against all types of projectiles, sharp weapons, fragments and shrapnel, fire, etc., that can be integrated into the soldier's personal protective equipment and into the armour used by military platforms (land, naval and air). |

As long as there are casualties due to damage caused by ballistic threats, explosions, stab wounds, etc., solutions are necessary to guarantee the protection of soldiers and to reduce these casualties as much as possible. One solution is to increase the level of protection against such threats, both for individual soldiers and for the platforms on which they are part of a crew.

Currently, platforms requiring a high level of protection are often quite heavy, largely due to the increased weight of the passive protection system integrated into the platform. For the soldier, although the materials used in vests, helmets and other protections have improved considerably, other heavy materials are still being used, which hinder the mobility or ergonomics and comfort of the soldier and are still not capable of impeding trauma wounds from projectile impacts.

The greatest difficulty from a technological point of view is the development of materials that are lightweight and at the same time offer better mechanical performance than current materials. It is also a challenge to manufacture these materials on a macroscopic scale and to integrate them into larger systems such as individual protection for the soldier or protection for the structure of a platform.

In recent years there have been notable advances in materials technologies. Thus, it is worth mentioning the development of nanostructured composite materials or new high-performance ceramics as materials to be incorporated in the short and medium term, and others such as auxetic structures or non-Newtonian fluids, which are at a lower technology readiness level and could be included (if feasible) in the longer term. More exclusively, the use of multi-material laminar structures (hybrids) is foreseen in the short and medium term for platforms, while high-performance synthetic fibres and even three-dimensional fabrics are foreseen for soldiers.

During the period of validity of the ETID, it is planned to continue with the execution of projects under development or recently completed, aimed at developing and integrating some of the aforementioned technologies in the combat system and on specific military platforms, as well as to promote or support new RDI developments, which will enable the incorporation or validation of new materials for defence applications. Given that materials technology has an important dual use, a high contribution of external funding is expected for the development of these projects, particularly at low and medium readiness levels. Therefore, the efforts of the Ministry of Defence will focus on the development and integration stages in soldier and military systems, including testing and validation.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **Materials – Reduction of platform and soldier signatures** |
| Development of new materials to improve the survivability of platforms and military personnel by reducing their detectability. These materials would allow the reduction of the signature (radar, IR, acoustic, visible, etc.) of the platforms (land, naval and air) and of the soldier, improving their stealth capability and making their visibility more difficult for the potential enemy. |

From a strategic point of view, reducing the detectability of platforms and soldiers is very important, both to increase the chances of survival in operational scenarios and to use the surprise element on the potential enemy and maximise the effectiveness of an attack.

Although many military platforms have greatly reduced their detectability, there are increasingly advanced systems capable of detecting them: sensors with improved performance used in the detection of different types of systems and personnel, algorithms used to process the data received by these sensors, etc.

Platform and soldier signatures need to be reduced in all their variants (radar, infrared, visible, acoustic, etc.) to make them more difficult to detect or to generate confusion when determining the type of object being detected. As far as the soldier is concerned, it is no longer enough just to camouflage the troops so that they go unnoticed in the environments where they are deployed. IR and radar signatures generated by the increasing amount of electronic equipment used must be taken into account. The development of new materials represents an opportunity for their integration and application in future military platforms and in future soldier systems. These new materials will result in platforms and soldiers that are more difficult to detect by different types of optical, IR, acoustic or radar sensors.

The greatest difficulty from a technological point of view is the development of materials that provide signature reduction capabilities over the widest possible range of frequencies (there is even talk of the same material being capable of reducing different types of signature). In addition, these materials must have other properties, such as mechanical resistance, resistance to degradation, etc., that allow them to be integrated into a more complex system and to be compatible with other elements of the system in which they are incorporated.

In the coming years, it is planned to promote the development of a series of RDI projects that will allow the development of new materials and their incorporation as signature reduction elements applicable to military platforms and soldiers' equipment.

It is envisaged that part of these developments will be supported by funding from outside the Ministry of Defence.

| HARNESSING THE CIVILIAN TECHNOLOGY PUSH |
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| **Space – Use of small satellites and pseudo-satellites in defence applications** |
| Development of small satellites and pseudo-satellites adapted to the requirements of defence missions, as well as systems capable of launching these small satellites into orbit, thus reducing the overall time and cost of their deployment compared to existing solutions. |

Due to the long period of development, manufacturing and commissioning of satellites in space, as well as the cost and their useful life, alternative technological solutions are needed to complement the large satellite missions serving the Armed Forces in their different areas of interest (communications, Earth observation, navigation, positioning and timing, space situational awareness).

In this context, the technology of small satellites and pseudo-satellites or HAPS (high-altitude pseudo-satellites), developed in the so-called "New Space" context, offers new possibilities. These include support for conventional large satellite missions; swarm or constellation formation; and even the use of other ranges of the electromagnetic spectrum, both for ground-to-satellite or satellite-to-satellite communications, to form distributed satellites, or as unitary satellites for specific and localised missions in a given area. They can also be used as orbit experimentation platforms for components and payloads for future missions.

In addition, the ability is needed to launch these small satellites into orbit by means of small launchers (rockets, propelled by either liquid or solid fuel, launched from the ground, from aircraft or from hot-air balloons, etc.), thus reducing the overall time and cost of their deployment compared to existing solutions.

Although small satellite and HAPS technology itself has a high technology readiness level, there are technological challenges associated with its use in defence related to the use of V/IR (visible/infrared) observation payloads that require very high resolution, power maintenance, nanotechnology, highly efficient deployable solar panels, on-board processing capabilities for the data acquired, etc., as well as prior studies for the development of constellations or launches from air platforms or hot-air balloons instead of ground launches.

The high dual use of these technologies means that a significant part of these developments is supported by funding from outside the Ministry of Defence. In the coming years it is therefore planned to take advantage of the development of small satellites, HAPS and launchers that are being developed for civilian applications and to promote their adaptation to defence needs, combining specific investments in payload development with activities for testing and validating solutions, and contributing technical criteria and means to promote advances in this field.

| ENHANCEMENT OF HUMAN CAPABILITIES |
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| **Technologies for the dismounted soldier** |
| Development of technologies to improve the performance of the various advanced systems and equipment carried by dismounted soldiers, in order to enhance their capabilities, mainly in terms of fire efficiency, situational awareness and integration with external sensors and systems, survivability, sustainment, mobility and training capacity. |

Dismounted soldiers must currently face a wide variety of missions, often carried out in extreme environments involving risk or high physical or cognitive demands, which require advanced equipment and systems to help them perform their duties in an effective and safe manner. Current technological progress offers many possibilities to improve the characteristics and performance of these systems, which makes their incorporation for use in the Armed Forces an objective of this Strategy.

Due to the range of missions to be accomplished, these systems need to be easily integrated into a common and scalable architecture, depending on the needs of the operation. These architectures are being defined and developed in an international context, with a view to attaining standards that facilitate the updating of each module, imposing restrictions on the interfaces. In addition to the architecture, improvements are required in the other subsystems, both in terms of weight, volume and power demand reduction, as well as in terms of their specific performance. While some of these improvements are addressed in other technological objectives (passive protection, signature reduction, exoskeletons, etc.), this objective foresees advances in some of the other subsystems, such as:

- Improved soldier situational awareness and fast and secure connectivity with all types of sensors, C2 and unmanned systems, positioning and localisation in non-GNSS environments, local information fusion and use of advanced graphical interfaces and augmented reality.
- The use of high-definition displays and sensors and the on-site exploitation of information.
- Improved power supply, using new batteries, solar cells and fuel cells that allow the reduction of the physical load by means of a centralised management.
- Improved fire efficiency, through weapon performance enhancement and its integration with the soldier.
- The use of smart textiles – incorporating sensors, electronics and other wearables – or textiles used for the management soldier's thermal regulation in areas with extreme climatic and environmental conditions.

Due to the high dual use of a significant part of the aforementioned subsystems, the Ministry of Defence plans to combine support for some of these subsystems with others funded by external sources in the coming years, emphasis being placed on integration into the system's architecture and the testing of these advances in close to real conditions.

| ENHANCEMENT OF HUMAN CAPABILITIES |
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| **Exoskeletons for defence applications** |
| Development of exoskeletons to support the soldier in missions requiring a high level of physical effort, with a view to facilitating individual mobility and the transport and handling of›loads, reducing physical fatigue and preventing possible injuries. |

The number of systems carried by soldiers has gone up over time, and is expected to continue to rise as new equipment and technologies emerge, resulting in an increase in the load to be carried. The technological challenge of reducing the weight of this equipment (introduction of new, lighter materials, re-dimensioning of components, etc.) has created a need for innovative systems to alleviate the physical load soldiers have to bear and provide troops with increased mobility capabilities. In addition, systems are also sought to assist individuals in activities related to the transport of loads, such as in maintenance work or the assembly and disassembly of installations.

In this context, it is planned to develop exoskeletons that assist individuals in their movement and reduce the effort they must make. In physical terms, exoskeletons provide benefits in terms of increased strength, endurance and even speed and the ability to move in difficult terrain. In operational terms, the benefits would be many: increased load capacity, shorter travel times, greater range of movement, reduced fatigue and tiredness of the soldier, greater strength to move heavy items, ability to operate for longer periods of time, etc. The use of these systems would not only facilitate the transport of equipment by the soldier, but also the handling of heavy loads and the individual’s own movement.

Exoskeletons are being implemented in various areas of the civil sector, and these developments need to be adapted for specific defence applications, for which key aspects such as system weight, resistance, ergonomics, level of assistance provided or system regulation capacity will have to be optimised. On the other hand, robotic or active exoskeletons still have a low technology readiness level, and significant technological challenges need to be resolved in this area (optimal, synchronised operation with the individual, miniaturisation and integration of sensors, actuators, batteries, communications systems, etc.).

The highly dual nature of this type of system means that a significant part of the advances in this field can be supported by funding from outside the Ministry of Defence intended for dual purposes. Therefore, in the coming years, the Department’s efforts will be directed towards testing the development of passive exoskeletons and promoting projects specifically dedicated to their adaptation for defence purposes. Moreover, depending on how the technology evolves, the development of technological demonstrators of robotic exoskeletons applied to specific practical cases in the defence environment could be contemplated. In addition, it is envisaged to provide end-user criteria for all passive or active developments, of different types and performance, which can be applied to the military field. Participation in possible European initiatives in this field is also foreseen.

| POTENTIALLY DISRUPTIVE TECHNOLOGICAL ADVANCES FOR DEFENCE |
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| **Advanced training through simulation** |
| Develop multi-user LVC (Live/Virtual/Constructive)[1] simulation means that make it possible to achieve the most realistic level of instruction and training possible for the Armed Forces, that incorporate mechanisms for monitoring personnel behaviour for subsequent analysis, and that enable them to carry out the missions entrusted to them in the planned scenarios efficiently and safely. |

Force readiness is considered a cross-cutting capability. The means for the individual and collective training of units must enable personnel to be instructed in the use of weapon systems and in how to respond to the threats present in the operational scenarios, in order to be able to carry out the missions and tasks entrusted to them effectively and safely.

Live, immersive virtual and constructive simulation are disciplines that can bring major benefits to the Armed Forces, including cost savings compared to the use of real systems (ammunition, fuel, human lives, extending the operational life of weapon systems, etc.), the possibility of repeating the exercise until it is performed correctly, or of creating alternatives to events that occur in exercises through a variety of simulated scenarios and situations. These benefits apply to all domains, including cyber defence.

The main technological challenges associated with this objective are related to achieving a high level of immersion (use of haptic devices, multi-user rooms for collective training, realism of the projected simulation, etc.), achieving a high level of interoperability between federated users in the same simulation (extensive use of standards, use of reusable resources, etc.), enhancing augmented and hybrid reality in order to provide the soldier with context information of the scenario, combining real and simulated elements, as well as realistically reproducing the logic of the behaviour of entities and groups in both virtual and constructive simulations.

The high dual use of simulation makes it possible to take advantage of civilian developments in simulation, especially those related to the operation of platforms (land, sea and air), developments in the video game industry and in the test benches of the cyber defence industry.

In the coming years, defence actions will be aimed at supporting RDI projects geared toward training in specifically military situations, where maximum use is made of the possibilities provided by distributed simulation (through the use of interoperability standards), and the incorporation of other technologies (AI, haptic devices, etc.), which will improve the training capacities of these systems, as well as the immersive and logical realism of individual and multi-user simulations, combining investments from within and outside the Department for this purpose.

[1] ***Live:*** a simulation involving real people operating real systems. Military training events with real equipment are live simulations.
***Virtual:*** a simulation involving real people operating simulated systems. Virtual simulations immerse an individual in a simulated scenario. Augmented and hybrid reality would be in the middle ground between the aforementioned two types of simulation.
***Constructive:*** a simulation involving simulated people operating simulated systems. Real people stimulate (provide input to) such simulations, but do not participate in determining the outcomes.

| ENERGY SUSTAINABILITY |
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| **Power generation and energy efficiency in isolated bases and infrastructures** |
| Reducing energy dependence and improving energy security at bases, camps and other off-grid infrastructures by developing technologies and adapting and validating them for use in the military environment. |

The generation of electric power at bases and camps in areas of operation is currently carried out, in most cases, using diesel electro-generator sets due to the non-existence or unreliability of local electrical grids. Despite their tactical advantages, their use implies a high logistical footprint due to significant associated financial and protection costs, maintenance requirements and reduced energy efficiency. Other off-grid infrastructures have a similar energy dependency.

The improvement of energy efficiency in these installations must be approached from several angles. The integration of power generation systems based on on-site available renewable resources can significantly reduce the need for fuel consumption in generator sets. On the other hand, there is a need for improved grid management through smart grid technologies. Their use can enable the integration of generator sets, new energy sources and storage systems to ensure grid stability and improve energy management by centralising and automating the management of non-critical electrical charges. Other areas for improving efficiency and resilience in operation areas include on-site fuel production on a small scale, improving the efficiency of air conditioning and hot water systems, and developing building systems and materials that reduce the demand for air conditioning.

This is an area of high dual use, in which the technologies involved have very high levels of readiness and are being widely developed in the civil sector, with significant technological capability at national level. However, a certain level of adaptation to the military environment is required due to more demanding environmental and integration conditions in areas of operation (transportability, vulnerability, etc.). It should be noted that in the development of smart grid systems, special emphasis should be placed on interoperability and security against various threats (cyber-attacks, EW, etc.).

In the coming years, defence actions will therefore be aimed at promoting technical-operational validations, as well as adaptations of targeted developments in specific cases for use in the area of operations, mainly storage systems, smart grids and integrated generation systems. In other areas, technology surveillance activities will be carried out in order to gain knowledge of the extensive research applied in the civil sector, together with the promotion of dual developments by means of external instruments from outside the Department. International cooperation activities will also be promoted, as national capabilities are complementary to others existing in European countries and there is a broad interest in developing joint capabilities.

| ENERGY SUSTAINABILITY |
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| **New propulsion systems for manned and unmanned platforms** |
| Development of hybrid and electric propulsion systems on manned platforms and unmanned systems in order to reduce the dependence on fossil fuels for platform propulsion and to improve the mobility and stealth capabilities of the systems. |

The requirements for improving the propulsion systems of manned platforms are becoming increasingly demanding, due to various factors that depend on the type and operating environment of the platform. The increased weight of passive protection, improved mobility capabilities, greater flexibility in power generation to feed electrified systems, the increase in payloads, some with high energy consumption, or the need for some platforms to operate in stealth mode, with reduced thermal and acoustic signatures, are some of these factors.

Regarding unmanned systems in all domains, there is an important niche to develop hybrid or electric systems with new storage technologies, bridging the gap between small electric propulsion systems and large fossil fuel propulsion systems.

Finally, it is necessary to consider the development of deployable systems for recharging the different energy carriers for these platforms, so that they can maintain similar operability to that of conventional platforms.

At technological level, the rapid development of dual technologies with a strong boost in the civil sector, both regarding electrochemical storage and fuel cells, could be a determining factor in achieving this technological objective. It is worth noting the significant momentum for civilian application development programmes foreseen in the next EU budgetary framework.

Most of the activities planned for the coming years focus on the development of demonstrators to assess the feasibility of new propulsion technologies in the military domain. In the area of manned land platforms, the experience of previous projects carried out in the framework of the COINCIDENTE programme will be used as a basis. For unmanned platforms, the development of air and naval platforms with advanced hybrid battery or fuel cell propulsion systems will be encouraged. Finally, the advisability of developing demonstrators for recharging stations for electricity, hydrogen or other fuels will be studied in case bottlenecks are identified in the adaptation of civilian standards to the military environment. Likewise, activities will be promoted for the development of technologies with a lower level of readiness, which could be carried out through external instruments, such as the development of the national capability of fuel cell technologies for dual use in different applications or, in the specific case of naval platforms, the study of the application of superconductivity in propulsion

| DIGITAL TRANSFORMATION |
| --- |
| **4.0 technologies for the Department's digital transformation** |
| Harnessing progress in the civil sector of the so-called 4.0 technologies to support the Department's digital transformation process through initiatives with a high level of technological innovation. |

The application of the new technologies that make up the Industry 4.0 concept (artificial intelligence, Big Data, blockchain, Internet of Things, virtual simulation, augmented reality, predictive maintenance, robotics, additive manufacturing, digital twin, hyperconnectivity, etc.) has led to a deep transformation of the processes and services provided by organisations and society in general.

The Ministry of Defence is no stranger to this change and for some time now the digital transformation of the Department has been a priority, as reflected in the Ministry of Defence's Action Plan for Digital Transformation (PATD). The rapid and constant advance of ICT driven by the civil sector, combined with the specificities that arise from their application to the particular needs of the Department, lead to the promotion of technological innovation activities that speed up this process of digital transformation.

Specifically, the wide variety of advances in the field of artificial intelligence, including those related to Big Data and data analysis, advanced knowledge representation or automatic learning and reasoning, as well as technologies to increase secure data transmission within the Ministry, data processing on the cloud and hyperconnectivity, are the focus of a significant part of the interest of this objective.

In this context, one area of particular relevance is the modernisation of logistics bases and installations, whose operation can benefit greatly from the incorporation of these new technologies to improve the planning and automation of their processes, connectivity, knowledge management, security of the installations and of the operation itself, and the maintenance of systems. Various initiatives of the Forces have been moving in this direction (e.g., COLCE [concentration of the Army's central logistics bodies]; BACSI [Air Force connected, sustainable and smart air base]; and Integrated Logistics Support in the Navy).

This technological objective complements other objectives that also take advantage of 4.0 technologies (predictive maintenance of military platforms, automatic and intelligent analysis of large volumes of sensor data, etc.), although it pursues its application with a comprehensive vision: to achieve greater efficiency in the Department's most critical services and processes.

In order to address this, in the coming years the plans are to focus on those activities with a greater technological content and innovative nature and whose application in defence presents significant differences compared to the civil sector.

The high dual use of many of these technologies means that a significant part of these advances will be made on the basis of funding from outside the Ministry of Defence.

| INITIAL TECHNOLOGICAL CAPABILITY DEVELOPMENT |
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| **Technologies for the development of high-power laser weapons** |
| Design, development and integration of high-power laser directed-energy weapon (LDEW) systems for use in military and security applications, providing additional self-defence and response capabilities. |

All forecasts suggest that the application of laser weapons in defence, once they have reached the necessary level of readiness, could replace a significant part of conventional weaponry and thus be of a disruptive nature.

In particular, laser weapons have multiple applications in defence: destruction of air platforms, mainly RPAS (especially operating in swarms), CRAM (countermeasures against rockets, artillery and mortars), missiles, self-protection of ships and ports against suicide attacks from small boats, self-protection of land platforms and critical facilities (bases in operations) from suicide attacks from land vehicles, destruction of land or naval platforms, non-lethal applications such as disabling land or naval platforms by destroying wheels, engines, detonating explosives, disabling IEDs, and destroying all types of systems such as sensors, radars, weapon systems, etc.

The development of the systems gives rise to multiple technological challenges, including determining the active medium of the laser source, obtaining the necessary power while maintaining an adequate size, weight and power supply, optimising factors (wavelengths, pulse duration, materials, etc.) to obtain the maximum destruction capacity and beam quality, among others. However, as all technological challenges are extremely interrelated, to develop an end system it only makes sense to approach the system as a whole and on the basis of the type of target, installation site and the need for distance and time for destruction. Also of particular relevance are the power supply needs, which are addressed in the technology objective “Energy systems for defence applications requiring high electric power pulses”.

In the coming years, thanks to funding from both within and outside the Department, the development of the SIGILAR[2] project, aimed mainly at C-RPAS applications and against small vessels, is foreseen to continue and to provide support to the development of other technological demonstrators. This will enable the national technological fabric to design and develop medium-range systems, as well as to participate in European consortiums that develop complete systems with advanced characteristics.

[2] High-power pulsed laser guidance system for military applications, from the 2018 call of the COINCIDENTE programme.

| INITIAL TECHNOLOGICAL CAPABILITY DEVELOPMENT |
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| **Technologies for RF directed-energy weapons** |
| Development of radio frequency (RF) directed-energy weapon technologies, with the aim of being able to address in the future the development of electronic attack systems that are capable of generating sufficiently high levels of RF power to temporarily disable or even destroy a threat's electronic systems. |

DEW-RF (radio frequency directed-energy weapons) could introduce deep changes in future operational scenarios, providing new capabilities or exerting a multiplier effect on existing ones. These are systems capable of generating RF power levels high enough to temporarily disable or even destroy a threat's electronic systems. This type of weapon could disable or destroy the electronic guidance systems of platforms (aircraft, battle tanks, etc.), causing them to behave erratically or become inoperative or be directed towards command, control and communications systems, degrading their combat capability.

Potential applications for such weapons include countering improvised explosive devices (IEDs), remotely stopping suicide vehicles, protecting aircraft against missiles and neutralising unmanned aerial vehicles.

The main technological challenges relate to the development of electronic devices for the generation of high-power RF signals (oscillators, amplifiers, modulators, etc.), for the generation of the high voltage levels necessary for the operation of these devices (Marx generators, etc.), as well as others related to the generation and emission of high bandwidth RF pulses or UWB (antennas, etc.).

Currently, the capacity of the technological fabric to develop RF directed-energy technologies is very limited. However, several national companies have a high level of expertise in high-power RF technologies for defence systems (radar, ECM, etc.), which would facilitate the potential development of the former.

Therefore, the ambition in this area for the coming years is to promote the development of projects that may boost national capability in the key technologies that form part of the different electronic devices or subsystems of a DEW-RF system, so that more ambitious projects can be addressed at national or European level.

Given that some of the applications of this type of system are common to the security field, it is envisaged that part of these developments will be supported by funding for dual purposes from outside the Ministry of Defence.

| INITIAL TECHNOLOGICAL CAPABILITY DEVELOPMENT |
|---|
| **Energy systems for defence applications requiring high electric power pulses** |
| Research into on-board power systems capable of supplying the necessary energy for new systems requiring high electric power pulses, such as laser directed-energy weapons, electromagnetic guns or active armour. These developments comprise both power storage systems enabling fast charge/discharge cycles and associated power electronics. |

The development of directed-energy weapons (microwave, laser, etc.), railgun or active protection systems substantially increases the strain on the platform's electrical system, as they require very high-power pulses for very short intervals. Direct connection of these systems to the platform's electrical system could cause voltage drops affecting sensitive electronic equipment on board the platform. It is therefore necessary to develop new electric power systems to meet these new power requirements without affecting the rest of the platform, enabling defence capabilities against asymmetric threats such as mini-RPAS in the medium term or more demanding directed-energy weapons in the longer term.

Such systems include fast-response flywheels, large-scale supercapacitors or mixed electrical storage systems, as well as power electronics systems capable of supporting such loads. These types of technologies are currently under development for civilian applications, such as grid management and grid quality improvement. Given that their state of readiness is in many cases low to medium, these are dual technologies whose development will be driven by the civil sector, although their integration on platforms is a major challenge, considering the high power level required by some of the aforementioned defence applications.

Given the limited national capacity in this field, the ambition of the Ministry of Defence concerning the development of storage systems for these applications is focused on the technological surveillance of possible uses of these technologies, support for applied research in dual developments through external instruments and a possible demonstrator development project in the medium term. With regard to power electronics, the ambition is to promote a certain degree of national capability-building for the development of tailor-made or laboratory level components, as well as to promote participation in multinational developments, which will enable future dual developments.

| INITIAL TECHNOLOGICAL CAPABILITY DEVELOPMENT |
| --- |
| **Detection technologies for the development of active protection systems** |
| Development of projectile detection and tracking technologies intended to form part of active protection systems with C-RAM (counter rocket, artillery and mortar) air defence capability, for use in the protection of bases and camps, land platforms and naval surface platforms. |

Due to the emergence of new types of increasingly effective and lethal projectiles (high kinetic energy piercing warheads, tandem and triple warheads, new design concepts for hollow charges and swooping attack vectors, etc.), the passive and reactive protection measures used extensively are not always effective, leaving the Force in a situation of vulnerability. In the face of this threat, the approach that is proving to be most effective is the incorporation of active protection measures, understood as systems capable of detecting and neutralising projectiles directed against their own forces before impact.

In an active protection system, given the nature of the threat, there are several sequential processes that depend on each other, which have to be executed with high precision and with critical response time requirements. These processes are organised into four stages: threat detection and identification; target trajectory tracking; ballistic calculation; and, finally, interception. Of these, the first stage is the most critical, as it is the enabler of the subsequent stages, which in turn require very powerful processing and adequate actuators to deal with the threat.

Some of the technological challenges associated with these systems are the hybridisation of different sensors (EO/IR, radar, acoustic, etc.), their capacity to operate in real time and under different environmental conditions, the radius of coverage, the capacity to identify the type of threat, the capacity to respond to concurrent threats, the refresh rate for monitoring trajectories, the treatment of multi-signal redundancy, the use of effective means of action, their adaptation to the requirements of the platforms on which they will be installed, etc.

Given the high technical complexity and the diversity of the technologies involved in a system of these characteristics, this objective will focus on promoting an initial capability in the national technological fabric that will enable it to participate in subsequent larger projects, either at national or international level. Therefore, in the coming years, there are plans for the development of projects that will initially focus on the first of the four stages mentioned above, i.e., projectile detection and tracking, with a view to having portable demonstrators that can subsequently be completed and adapted to the specific requirements of the protection of bases and camps, land platforms and naval surface platforms, and may form part of a complete C-RAM system.

| MONITORING OF EMERGING TECHNOLOGIES WITH FUTURE DEFENCE APPLICATIONS |
| --- |
| **Emerging technologies with potential future defence applications** |
| Technology watch on advances in emerging technologies or those with a low readiness level, the future development of which could open up new possibilities for defence RDI or have important implications, even disruptive effects, in the defence and security context. |

There is a wide range of technologies that are currently still at an early stage, although there is significant potential for them to lead to major changes in the defence sector in the future. These technologies are being developed primarily in academic and research centres.

As they have low or very low technology readiness levels, their dual-use possibilities are complete. In this regard, the Ministry of Defence does not plan to make specific investments to promote their development, except in particular cases, as there are instruments in the National RDI Plan designed for this purpose. The ambition for these technologies is to carry out technological surveillance of the advances made by the national research fabric, with a view to serving as a link between the national research community and the opportunities that may arise in international organisations dedicated to defence RDI, in which Spain participates. It is also expected to be able to provide support and guidance to all these areas in relation to their possibilities of application in defence.

The following is a list of those already known, although it is important to bear in mind that this list is expected to grow during the Strategy's period of validity:

- **Quantum computing.** Quantum computing uses properties of quantum mechanics to process information, making it possible to perform several operations simultaneously, which gives it exponential power. This capability will provide the possibility to break current cryptographic keys in a short time, known as ***quantum cryptanalysis***. To resist attacks of this type, which would put the nation's highly sensitive information at risk, the development and implementation of ***post-quantum cryptography*** will be necessary, and it is considered important to start investing efforts in this area. The development of new algorithms will allow complex problems associated with mission planning and logistics (process optimisation, supply chain), artificial intelligence, quantum simulation, among others, to be resolved. The main challenges facing quantum computing today are found in hardware: the instability of qubits, which are highly sensitive to environmental perturbations and generate errors in operations, makes it necessary to advance in quantum error correction, and in the quality of the qubits themselves. Research is also needed on materials, such as superconductors, in order to increase the operating temperature of these systems, which currently operate close to absolute zero. Another of the main problems is scalability, which allows the number of qubits to be increased in order to gain computational capacity without losing quality. It is also important to advance on the software side, in the development of the algorithms needed to be able to use these computers.
- **Quantum communication and information.** The use of ***quantum cryptography***, which includes ***Quantum Key Distribution (QKD),*** can be applied in the various communication channels to ensure a very high level of security of the information transmitted and to prevent it from being intercepted. Equipping satellites with QKD capability can enable communication between users over long distances and different media (land, sea, air, satellites). Among the challenges to guarantee the transmission channel, work must be done to create quan-

tum repeaters with integrated quantum processors that allow information to be sent, while maintaining quantum encryption, between nodes at a distance that prevents the attenuation of the photons normally used as qubits in media such as optical fibre or free space.

Also important is progress in quantum random number generators, which ensure that the key shared between sender and receiver is totally unpredictable. On the other hand, research is also needed on communication based on quantum entanglement (also known as quantum teleportation), which would allow data to be sent directly in a quantum state, gaining substantially in security. In this case, the major challenge would be to safely generate entangled photons on demand and to maintain their entanglement, especially over long distances.

- **Sensors and quantum metrology.** The development of sensors and quantum metrology will be applied to high-resolution, highly sensitive and more accurate measurements of physical parameters using quantum mechanics. This translates into quantum gravity sensors, magnetometers, accelerometers, gyroscopes or quantum clocks, among others. The development of metrology at nanoscopic level will support miniaturisation technologies. Key applications will be the detection of underground spaces, such as mines or tunnels; the synchronisation between multiple weapon systems, airships or satellite constellations; the creation of quantum/heterogeneous sensor networks for the analysis of complex scenarios, such as missile defence or the tracking of underwater targets, which increases capabilities in anti-submarine warfare; the creation of GPS-independent tools, allowing them to operate inside structures or in environments with countermeasures (jamming, spoofing) so that they are unalterable by an enemy; and the analysis of materials in the semiconductor industry. More disruptively and in the longer term, the possibility of creating quantum radars would make it possible to identify hidden aerial targets without being discovered.

  It strongly affects the field of photonics, where quantum devices in this area operate with a single photon (with applications in microsystems, nanotechnology, telecommunications), which implies the development of new metrics, references, methods and instruments to quantify the measurements, behaviour and characteristics of such devices.
- **Quantum simulation.** A controllable quantum system used to simulate or emulate other quantum systems. It can help in the study or development of materials with unusual physical properties, as well as in complex system simulation and optimisation problems. Applicable to simulations of molecules and chemical reactions for the research and design of new drugs, industrial catalysts or materials, such as bioproducts for CBRN countermeasures, room temperature superconductors or thermal and magnetic insulators, among others; the evaluation of performance and charging and discharging characteristics in newly designed, more efficient and higher energy density batteries for use on platforms would be another possible application. This technology depends in turn on the evolution of quantum computing technology, facing the same challenges: isolation from the environment to avoid decoherence problems, system cooling or reliability, among others.
- **Hypersonic regime propulsion.** Several countries are making significant efforts to develop hypersonic propulsion technologies, which require two propulsion stages: one, which allows supersonic speed to be achieved, and the other, based on the use of scramjets in which combustion takes place in the supersonic airflow. Although this is not a new technology, there are several technical problems, such as the use of suitable materials to withstand the strong overheating effects, which are being solved recently due to a major effort in RDI by some countries. This technology will give rise to air platforms, manned or unmanned, with multiple missions, including the launching of satellites into space, but may also replace intercontinental ballistic missiles as strategic weapons, as they have a much better chance of survival against medium- and high-altitude air defence systems because they do not use a ballistic trajectory in the terminal phase.

- **Electromagnetic propulsion.** In recent years, technological developments in electromagnetic propulsion systems have been intensifying as an alternative to conventional ballistic propulsion based on energetic materials or propellants. Electromagnetic propulsion technology allows a considerable increase in muzzle velocity as well as in the range of employment of artillery. In addition, the high velocity that can be achieved allows the design of charges based on purely kinetic effects, which also avoids the use of conventional high-explosive warfare charges. Therefore, in addition to the improved performance in terms of effectiveness and efficiency, it provides further improvements in terms of safety in use by avoiding the use of energetic materials and the logistical footprint. The use of this technology requires specific interior ballistic designs, as well as the development of power sources capable of generating very high-power pulses in a very short period of time. Moreover, despite being a military technology, there is a dual component in low TRLs with civilian high-speed rail EM propulsion.
- **Supercavitation propulsion.** There is an important trend towards the emergence of new underwater platforms using supercavitation propulsion systems, which allow high speeds to be achieved by avoiding friction between the platform and the water by generating a gas bubble. Although this is not a new technology, it has several technical drawbacks, such as the difficulty in changing course or the implementation of guidance systems, but these are being solved as a result of new investments in RDI by some countries, which are giving rise to new and increasingly sophisticated systems. Supercavitation propulsion, together with nuclear propulsion systems, are giving rise to strategic submarine weapons that make it possible to reach targets at high speed and cover great distances. This was previously only possible through the use of missiles.
- **Cognitive radar.** Development of cognitive radar architecture technologies, definition of adaptive cognitive radar waveforms and cognitive analysis of the electromagnetic environment leading to a cognitive radar system. Artificial intelligence (AI) and self-learning play a key role for the definition of signal processing techniques as well as for resource management. These sensors will be able to act more autonomously, improve their threat detection and localisation capabilities, and their robustness against adversary electronic countermeasures.
- **Nanophotonics.** This is the manipulation of light at the nanometre scale. It is of particular interest due to the properties of components manufactured at this scale, such as quantum well infrared photodetectors (QWIP), which have a very short response time and can be used to manufacture high-speed infrared cameras. In addition to EO/IR detectors, nanophotonics can be applied to other types of components such as optics, coatings, mirrors, etc. At national level, there is RDI capability in several areas, but no industrial manufacturing capability for detectors.
- **High sensitivity detectors in the visible and NIR (near-infrared) range for the development of new night vision systems.** The availability of new detectors with very high sensitivity in the visible and NIR ranges is leading to the development of new night vision systems without the need for image intensifier tubes. At present, their performance does not meet the operational requirements for most military applications, mainly due to the minimum illumination needed, but if achieved, they could represent a leap forward in night vision, in particular due to the high relevance of signal digitisation. The acquisition of connectivity capabilities of the different systems is also considered of high interest.
- **Synthetic biology.** A discipline of biotechnology that involves the engineering and manufacture or redesign of multicellular biological components or systems with specific characteristics and capabilities not found in nature. This involves the manipulation of DNA and the exploitation of the resulting molecules to scale up biological processes and produce significant quantities of new organisms and their products. The ultimate goal is to create

biological material that can be programmed to perform certain functions. Synthetic biology is active in a variety of sectors, from the chemical and pharmaceutical industry to the manufacture of new materials and the production of bioenergy (hydrogen, etc.). In the field of biomedicine, developments are expected to significantly improve casualty care and soldier training, such as the production of intelligent and personalised drugs (vaccines and specific CBRN treatments), the repair and regeneration of tissues and organs, cell reprogramming, e.g., of the immune system to combat infectious diseases, and the production of biosensors for physiological and cognitive monitoring. It is also possible to design biosensors for the detection and identification of CBRN agents, or the fabrication of pre-symptomatic diagnostic microarrays for rapid response to natural or synthetic pathogens or chemical agents. All these advances are proposed within strict ethical, moral, legal and regulatory frameworks to ensure an appropriate use of the technology.

- **New materials.** Advanced materials are technologies that enable the capabilities and performance of the systems of which they form part to be improved. Obtaining new materials with better mechanical and functional properties requires control of the structure from the nanometric scale of the materials and reproduction up to the macro-metric scale. This requires tools to design and faithfully simulate their behaviour and new manufacturing processes (additive manufacturing, synthetic biology, etc.) that facilitate the manipulation of structures on both scales. This will facilitate the production of stronger and lighter materials, with multiple functionalities (thermal, electrical, etc.) and capabilities that were previously unattainable (self-repair, self-cleaning, etc.)
- **Complex robotic architectures.** Although the greatest technological advances in the field of military robotics will come from the evolution in the levels of decision-making autonomy of the systems, particular advances are expected in autonomous systems with complex architectures that will give rise to the emergence of new applications and functionalities. Of particular note in this area are micro-sized robots (mainly UAVs), which will be able to operate in environments hitherto unmanageable by current unmanned systems. Also of note are humanoid robots, quadrupedal or with designs that mimic animal locomotion, with advanced features in terms of mobility in terrestrial environments. Another emerging discipline within robotics is trans- or multi-domain systems, which will have hybrid structures allowing them to operate in more than one domain of operation (UGV-UAV, USV-UAV, UGV-USV, hovercrafts, etc.).

## Relationship between the technological objectives of the ETID and the strategic RDI lines of the EECTI 2021-2027

| Specific level/scope of action | Technological objectives | Main relationship with the strategic RDI lines of the EECTI 2021-2027 |
|---|---|---|
| Defence applications with high technological requirements | Munitions guidance and advanced control technologies | – Protection against new security threats<br>– Artificial intelligence and robotics |
| | High-performance electronic technologies | – Photonics and electronics |
| | Electronic warfare solutions adapted to the current and future electromagnetic environment | – Protection against new security threats<br>– Photonics and electronics |
| | Military communications in complex environments | – Next generation Internet |
| | Solutions for cyber operations | – Cyber security<br>– Next generation Internet |
| Defence against asymmetric threats | Advanced land-based IED detection systems | – Protection against new security threats |
| | Counter RPAS systems | – Protection against new security threats |
| | CBRN threat control | – Protection against new security threats |
| Harnessing the civilian technology push | AI – Automatic and intelligent analysis of large volumes of sensor data | – Artificial intelligence and robotics |
| | AI – Technologies for predictive maintenance of military platforms | – Artificial intelligence and robotics<br>– Next generation Internet |
| | AI – Intelligent analysis of multiple sources of information for decision support | – Artificial intelligence and robotics |
| | Robotics – Unmanned land platforms for defence missions | – Artificial intelligence and robotics |
| | Robotics – Unmanned surface and underwater vehicles for defence missions | – Artificial intelligence and robotics |
| | Robotics – Innovative applications of RPAS in defence | – Artificial intelligence and robotics |
| | Materials – Passive platform and soldier protection | – Advanced materials and new manufacturing techniques |
| | Materials – Reduction of platform and soldier signatures | – Advanced materials and new manufacturing techniques |
| | Space – Use of small satellites and pseudo-satellites in defence applications | – Astronomy, astrophysics and space sciences |

| Specific level/scope of action | Technological objectives | Main relationship with the strategic RDI lines of the EECTI 2021-2027 |
|---|---|---|
| Enhancement of human capabilities | Technologies for the dismounted soldier | – Cyber security<br>– Protection against new security threats<br>– Artificial intelligence and robotics<br>– Next generation Internet<br>– Photonics and electronics<br>– Advanced materials and new manufacturing techniques<br>– Climate change and decarbonisation |
| | Exoskeletons for defence applications | – Advanced materials and new manufacturing techniques<br>– Artificial intelligence and robotics |
| | Advanced training through simulation | – Next generation Internet |
| Energy sustainability | Power generation and energy efficiency in isolated bases and infrastructures | – Cyber security<br>– Protection against new security threats<br>– Climate change and decarbonisation<br>– Sustainable cities and ecosystems |
| | New propulsion systems for manned and unmanned platforms | – Climate change and decarbonisation<br>– Sustainable mobility |
| Digital transformation | 4.0 technologies for the Department's digital transformation | – Artificial intelligence and robotics<br>– Next generation Internet<br>– Cyber security |
| Initial technological capability development | Technologies for the development of high-power laser weapons | – Photonics and electronics |
| | Technologies for RF directed energy weapons | – Protection against new security threats<br>– Photonics and electronics |
| | Energy systems for defence applications requiring high electric power pulses | – Climate change and decarbonisation |
| | Detection technologies for the development of active protection systems | – Artificial intelligence and robotics<br>– Photonics and electronics |

| Specific level/scope of action | Technological objectives | Main relationship with the strategic RDI lines of the EECTI 2021-2027 |
|---|---|---|
| Monitoring of emerging technologies with future defence applications | Quantum computing | – Photonics and electronics<br>– Cyber security |
| | Quantum communication and information | – Cyber security |
| | Sensors and quantum metrology | – Photonics and electronics |
| | Quantum simulation | – Photonics and electronics |
| | Hypersonic regime propulsion | – Advanced materials and new manufacturing techniques |
| | Electromagnetic propulsion | – Advanced materials and new manufacturing techniques |
| | Supercavitation propulsion | – Advanced materials and new manufacturing techniques |
| | Cognitive radar | – Artificial intelligence and robotics |
| | Nanophotonics | – Photonics and electronics |
| | Highly sensitive detectors in the visible and NIR (near-infrared) range for the development of new night vision systems | – Photonics and electronics |
| | Synthetic biology | – Precision medicine<br>– Infectious diseases<br>– New diagnostic and therapeutic techniques<br>– Protection against new security threats |
| | New materials | – Advanced materials and new manufacturing techniques |
| | Complex robotic architectures | – Artificial intelligence and robotics |

Table 9. Traceability of the ETID technological objectives with the strategic RDI lines of the EECTI 2021-2027.


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# APPENDIX C. Definitions

Throughout this Strategy, terms of such general use are used that it is convenient to define them and how they should be understood in this document.

Thus, the concept of research and development (R&D)[1] includes creative and systematic work carried out with the aim of increasing the volume of knowledge and devising new applications based on available knowledge.

The term R&D encompasses three types of activities: basic research, applied research and experimental development. *Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. *Applied research* is original investigation undertaken in order to acquire new knowledge. It is, however, primarily directed towards a specific practical aim or objective. *Experimental development* is systematic work, drawing on knowledge gained from research and practical experience, which is directed to producing new products or processes, or to improving existing products or processes.

The applied and targeted nature of defence RDI means that, in general, interest and investment is normally directed towards the applied research and experimental development stages. However, the increasing pace of technological progress is leading in many cases to a growing interest in defence in relation to basic research activities, because of their important future implications for defence and security.

Within the framework of defence RDI, two types of activities are usually considered:

- **Research & Technology (R&T).** Applied research activities aimed at capability development in new technologies that can be used in future weapon systems and equipment, as well as the verification of these technologies through technological demonstrations.
- **Development (D).** Application of the knowledge and results obtained from research to the development of new products or to the improvement of the performance of existing products, obtaining systems prototypes with functionalities close to end systems.

In order to understand whether an R&D project can be considered to fall within the scope of either of these two categories, the readiness of the main technological challenges present in the project is usually measured, challenges of lessor readiness being taken as a reference. For this purpose, the TRL (Technology Readiness Levels) scale, described in the following section, is often used, which establishes levels according to a technology's level of readiness in its application to a system to reach a specific functionality. Taking this scale as an indicative reference, R&T activities move in the range between TRL 3-4 and not usually above TRL 6, while development activities move in the range of TRL 7-8, levels at which the main technological challenges should already have been overcome.

[1] These definitions summarise or reproduce verbatim those included in the Frascati Manual, OECD, 2015.

In terms of timeframe, the results of development activities are usually carried out with a view to their incorporation into end systems in the medium term (between two and six years), while in the case of R&T activities they are carried out with a longer-term view, often extending over periods of more than a decade.

On the other hand, **technological innovation**[2] refers to the set of scientific, technological, organisational, financial and commercial stages, including investments in new knowledge, which lead or are intended to lead to the implementation of new or improved products and processes. R&D is just one of these activities and can be carried out at different stages of the innovation process, being used not only as the source of creative ideas but also to solve problems that may arise at any stage until completion.

In the defence domain, the concept of technological innovation often relates to the creation of new technologies, products, processes or services applied in a way that brings novelty and value to end users, allowing them to evolve and improve the way they conduct their operations or even lay the foundations for developing new operational concepts. While, strictly speaking, this "innovative" quality can be present in both R&T and development projects, it is often linked to the novel use in defence of mature technologies developed in the civil sector.

Another element worth highlighting is the interest of RDI in relation to TIB capabilities. When referring to **TIB technological capabilities**, what is being referred to is entities' capacity to tackle novel projects with a significant research or innovation component. These types of capabilities, often present in university departments or research centres, in SMEs and in big companies with a vocation for innovation, are the focus of interest in defence RDI. When referring to **TIB industrial capabilities**, we are also considering their production, commissioning and maintenance capabilities for end systems, as well as the provision of services.

## Technology Readiness Levels

The term Technology Readiness Levels (TRL) refers to a metric that enables the level of readiness of a technology (materials, components, devices, systems, etc.) to be quantified approximately in order to assess its possible incorporation into a complex system. The use of this metric will support decision-making in the use of new technologies or systems by determining whether they are in a state of research, experimentation and development suitable for the project or mission as a whole.

Although different agencies have made different definitions, almost all of them are similar, the most significant being those made by the US Department of Defence (DoD) and the North American Space Agency (NASA). The levels defined by NASA are shown in Figure 14 and also described in Table 10.

[2] While the Oslo Manual (OECD, 2018) includes a broader definition of the concept of innovation, in the field of defence RDI, the term "technological product and process innovation", used in the second edition of the Oslo Manual, is commonly referred to.

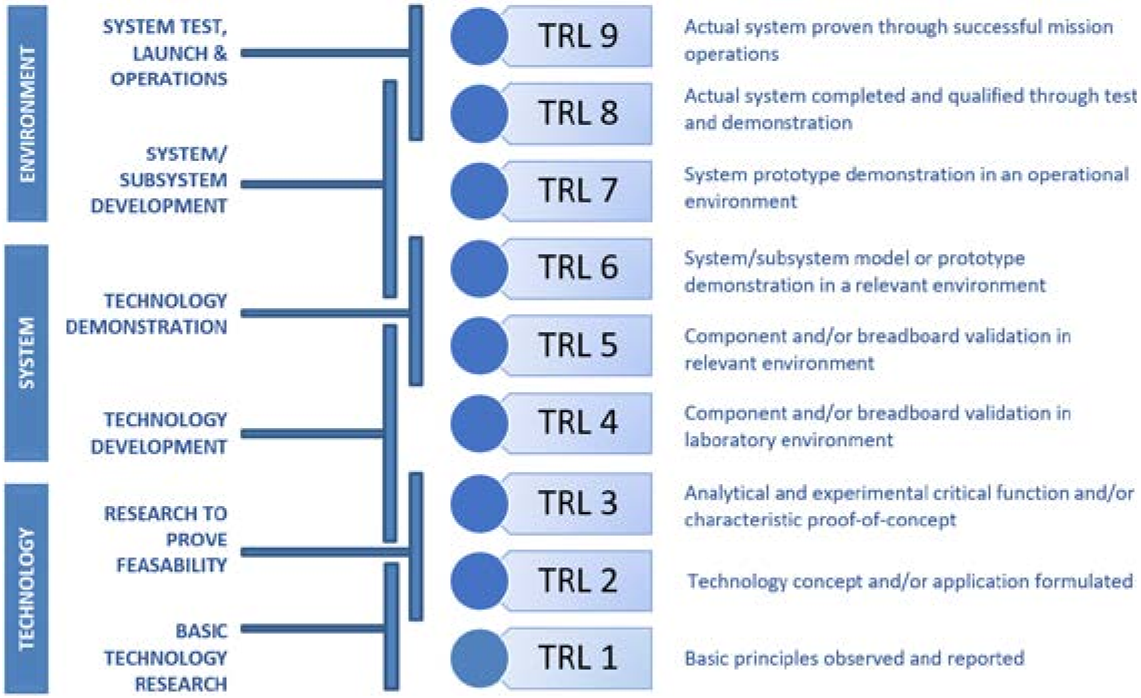


Figure 14. Technology Readiness Levels (TRL).

| Technology Readiness Level (TRL) | Description |
|---|---|
| **TRL 1. The basic principles of the technology have been observed and reported.** | A start has been made in identifying the basic principles of the technology and its R&D application. |
| **TRL 2. The concept or application of the technology has been formulated.** | Once the basic principles have been identified, practical applications can be defined. The application of the technology is theoretical, and no detailed experimentation or analysis is available to demonstrate it. |
| **TRL 3. Analytical and experimental critical function and/or characteristic proof-of-concept.** | This level includes analytical studies and laboratory tests to validate in a tangible way that the analytical predictions are correct. These studies and experiments should be part of the validation by proof of-concept of the applications/ concepts formulated in TRL 2. |
| **TRL 4. The technology components are validated in a laboratory environment.** | After the successful completion of proof-of-concept, the basic technology elements must be integrated to check that they all work correctly together to achieve the concept that establishes the desired performance levels for a given component. This validation should be designed to support the concept formulated previously, and should also be consistent with the application requirements of a potential system using this technology. |
| **TRL 5. The technology components are validated in a relevant environment.** | At this level, the reliability of the component being tested must increase significantly. The basic technology elements must be integrated in a reasonably realistic way with supporting elements so that the technology can be tested in a simulated environment or in a realistic environment. |
| **TRL 6. A system/subsystem model or prototype is demonstrated in a relevant environment.** | At this level there must be a representative model or prototype of the system/subsystem, which goes far beyond the model tested in TRL 5 and will be tested in a more realistic environment. In order to attain TRL 6, the test has to be fully satisfactory. |
| **TRL 7. A system prototype is demonstrated in an operational environment.** | This is a significant step up from TRL 6 as it requires the demonstration of a prototype of the actual system in an operational environment, such as a platform or as an integral part of a complex system. |
| **TRL 8. The actual system is completed and qualified through tests and demonstrations in real operating conditions.** | The technology has been tested in its final form under controlled conditions. In almost all cases, this level represents the end of actual system development for most elements of a technology. At this level, integration of the new technology into existing systems could take place. |
| **TRL 9. The actual system is proven through successful mission operations.** | The technology has been tested in its final form in real missions. In almost all cases, this level is the result of the last "bug-fixing" of the development of the real system. At this level, the integration of the new technology into existing systems could take place. |

Table 10. Description of TRL levels.

# APPENDIX D. Glossary of terms

| Term | Description |
|---|---|
| **AEI** | State Research Agency |
| **AI** | Artificial Intelligence |
| **CapTech** | Capability Technology |
| **CARD** | Coordinated Annual Review on Defence |
| **CBRN** | Chemical, biological, radiological and nuclear |
| **CDTI** | Centre for the Development of Industrial Technology |
| **CMRE** | Centre for Maritime Research and Experimentation |
| **COINCIDENTE** | Cooperation in scientific research and development in strategic technologies |
| **COVID** | Coronavirus disease |
| **CPoW** | Collaborative Programme of Work |
| **C-UAS** | Counter Unmanned Aerial System |
| **CUD** | Defence University Centre |
| **DDN** | National Defence Directive |
| **DPD** | Defence Policy Directive |
| **EDA** | European Defence Agency |
| **EDAP** | European Defence Action Plan |
| **EDF** | European Defence Fund |
| **EDF-R** | European Defence Fund – Research |
| **EDIDP** | European Defence Industrial Development Programme |
| **EECTI** | Spanish Science, Technology and Innovation Strategy |
| **EMAD** | Defence Staff |
| **ESIF** | European Structural and Investment Funds |
| **ETID** | Defence Technology and Innovation Strategy |
| **EU** | European Union |
| **EUGS** | European Union Global Strategy |
| **FCAS** | Future Combat Air System |
| **ICT** | Information and Communication Technologies |
| **INTA** | National Institute of Aerospace Technology |
| **JEMAD** | Chief of Defence Staff |
| **KSA** | Key Strategic Activity |
| **LAR** | Lethal Autonomous Robot |
| **MICINN** | Ministry of Science and Innovation |
| **NATO** | North Atlantic Treaty Organization |

| Term | Description |
|---|---|
| **NGF** | Next Generation Fighter |
| **NGWS** | Next Generation Weapon System |
| **OB Studies** | Operational Budget Studies |
| **OCM** | Military Capability Objective |
| **OFLP** | Long-Term Force Objective |
| **OPI** | Public Research Organisation |
| **OSRA** | Overarching Strategic Research Agenda |
| **PADR** | Preparatory Action on Defence Research |
| **PEA** | Special Armament Programme |
| **PEICTI** | Spanish National Plan for Scientific and Technical Research and Innovation |
| **PLANITEC** | Industrial and Technological Plan |
| **PNT** | Positioning, Navigation and Timing |
| **RC** | Remote Carrier |
| **RDI** | Research, Development and Innovation |
| **RF** | Radio Frequency |
| **RPAS** | Remotely Piloted Aircraft System |
| **S3** | Smart Specialisation Strategies |
| **STO** | Science & Technology Organization |
| **TIB** | Technological and Industrial Base |
| **TRL** | Technology Readiness Levels |
| **VUCA** | Volatility, Uncertainty, Complexity and Ambiguity |

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