R4.5 Body of Knowledge

Dissemination level: PU (public)

Grant Agreement Number:	**612678-EPP-1-2019-1-IT-EPPKA2-SSA-B**
Project acronym:	ASSETs+
Project full title:	Alliance for Strategic Skills addressing Emerging Technologies in Defence
WP number and tittle:	WP4 - Exploitation
Tittle of the deliverable:	Body of Knowledge
Deliverable number:	R4.5
Responsible partner:	University of Pisa
Contributing partners / fellows:	EWF; AAU; UBX; CENSEC; PRZ; FGB
Document's status	final

Document's development track:

	Version of the document	Organisation	Name, Surname	Date
Drafted by:	V.1	(list all authors)* University of Pisa EWF	Irene Spada Filippo Chiarello Vito Giordano Ana Beatriz Lopez Adelaide Almeida	June 2020
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Reviewed and Released by:	V.4	(Task leader)* UNIPI	Irene Spada	December 2023

** Note from the Project coordinator: draft document is expected from the task leader and can involve other partners; the review of the document is performed by the task fellows, including the WP leader.*

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Introduction

The ASSETs+ Body of Knowledge (BOK) is the ontology of concepts, terms and activities that make up a professional domain, as typically defined by the relevant learned society or professional association. The ASSETs+ BOK maps all the relevant competences needed for defence practitioners with respect to the technological scope of the project (Robotics, Autonomous Systems, Artificial Intelligence, Cybersecurity and C4ISTAR) and it will be a guidance document for the European Defence Sector. It is intended to provide a detailed breakdown of the knowledge required by any person working for or on behalf of Defence Sector bodies or organisations. The Body of Knowledge for the different technologies and for the defence sector is a key element for the exploitation strategy and it is strongly linked with both skills (demand and offer) and qualification. It is based on the *Technology roadmap* and on the *Skill Blueprint* and must be actionable, so detailed at very fine grain.

This document includes first an overview of the sector, with reference to the public investment and the competition in the market. Then, a description of the ASSETs+ project, goals, participants, and approaches are provided. Finally, the main part of the BOK is presented with concepts, definitions and relations. In particular, the definitions of the concepts and their relations derive from the previous analysis performed in the project involving academia and industrial experts, both in execution and validation. Thus, the BOK is not intended to produce new knowledge, rather to provide guidelines to connect the information and use the knowledge acquired and generated in the ASSETs+ project.

The context: the European defence and the ASSETs+ project

European Defence and Defence Industrial Base

The digital transformation of the last decades brings a re-shaping of many industrial sectors and defence is no exception. In recent years, the European Union (EU) has begun to promote initiatives in the context of defence to provide more resources, stimulate efficiency, facilitate cooperation and support the development of new capacities. The drivers of this transformation are the defence investment breakdown, the fragmentation of defence industry and the increase of global insecurity. The EU is looking for a stronger integration between defence systems of Member States in order to be more powerful in the global panorama, to avoid duplication of investments and to achieve strategic autonomy. Moreover, the European Commission has been encouraging industry and stakeholders to make the best use of existing EU programmes and tools and to address skills gaps and to foster new skills.

It is important to tackle the challenges of the sector concerning the technological development. In fact, the pace of the technology development's cycle nowadays it is not only faster but also more complex than in the past. Technological complexity is a concept linked to the need of different competencies to exploit the new technological knowledge, to the combination of different technologies in one product, and to the number of actors involved in Research and Development (R&D) process. To provide evidence of this increasing complexity, there are fighter aircrafts (combination of knowledge from engines, electronics, weapon-system, structural design, material) or the massive use of Information and Communications Technology (ICT) in weapon-systems (Belin, J. et al., 2019). Moreover, the paradigm of unilateral and linear technology transfer from military to civilian, typical of the period from the 1940s to the 1980s, has been overcome by a circular approach in which the multiplicity of actors and purposes pushes an integration (European Commission, 2008). In the last years, the number of dual technologies increased, especially in the field of Information Technology (IT) as a meaning of example, but not limited to what we can consider the advanced sensors that allows the real-time information gathering and sharing, or the tracing systems based on the Global Positioning Systems (GPS). So, the need to reshape the boundaries of civil and defence purposes is emerging, filling the gaps between civil and military and activating new synergies also involving more than one EU member states.

The technological domains under analysis in the ASSETs+ project, i.e. Artificial Intelligence, Robotics and Autonomous Systems, C4ISTAR[1] and Cybersecurity, are related to the area of dual use technologies. Therefore, a constant supervision of the evolution of these most promising research areas is necessary in order to gain a competitive advantage in the global panorama, both from the pure technical point of view and from the perspective of skills and knowledge necessary to correctly handle those technological developments.

Analysis of Public Expenditure and Investments in Defence

The commitment of European Member States in Defence sector can be measured with the public expenditure and investments in Defence and the Gross Domestic Expenditure in Research and Development (known as GERD). Figures 1 and 2 report the public expenditure and investments in Defence respectively worldwide in Europe in 2021[2], and Figure 3 presents the evolution of GERD from 1991 to 2020 for US, Europe, France and the aggregated data for OECD countries, as registered in OECD repositories[3].

[1] C4ISTAR is an acronym for Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance.

[2] Data retrieved from SIPRI repositories, available at: https://www.sipri.org/databases/milex , accessed May 2022.

[3] Data retrieved from OECD repositories [OECD (2022), Gross domestic spending on R&D (indicator). doi: 10.1787/d8b068b4-en (Accessed on 01 June 2022)] available online at: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm, accessed May 2022. The graph of Figure 8 shows trends of United States and France, the greater expenditure in Defence (Dr Diego Lopes da Silva, Dr Nan Tian, Dr Lucie Béraud-Sudreau, Alexandra Marksteiner and Xiao Liang, (2022), Trends in World Military Expenditure, 2021, SIPRI. https://doi.org/10.55163/DZJD8826), and aggregated data of the European Union 27 countries (EU-27). The zone EU-28 includes Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and Sweden. The OECD zone includes all Member countries of the OECD i.e. Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

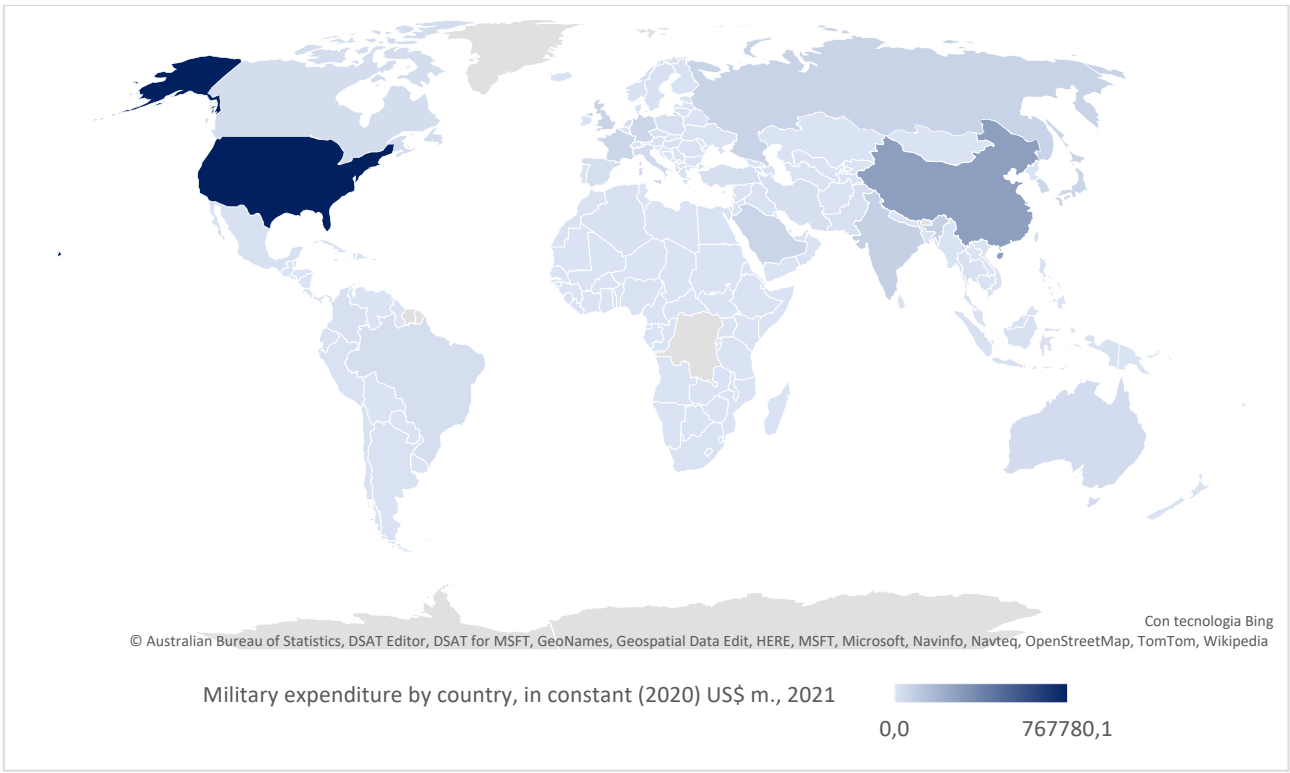

Figure 1 - Distribution of military expenditure in the World.

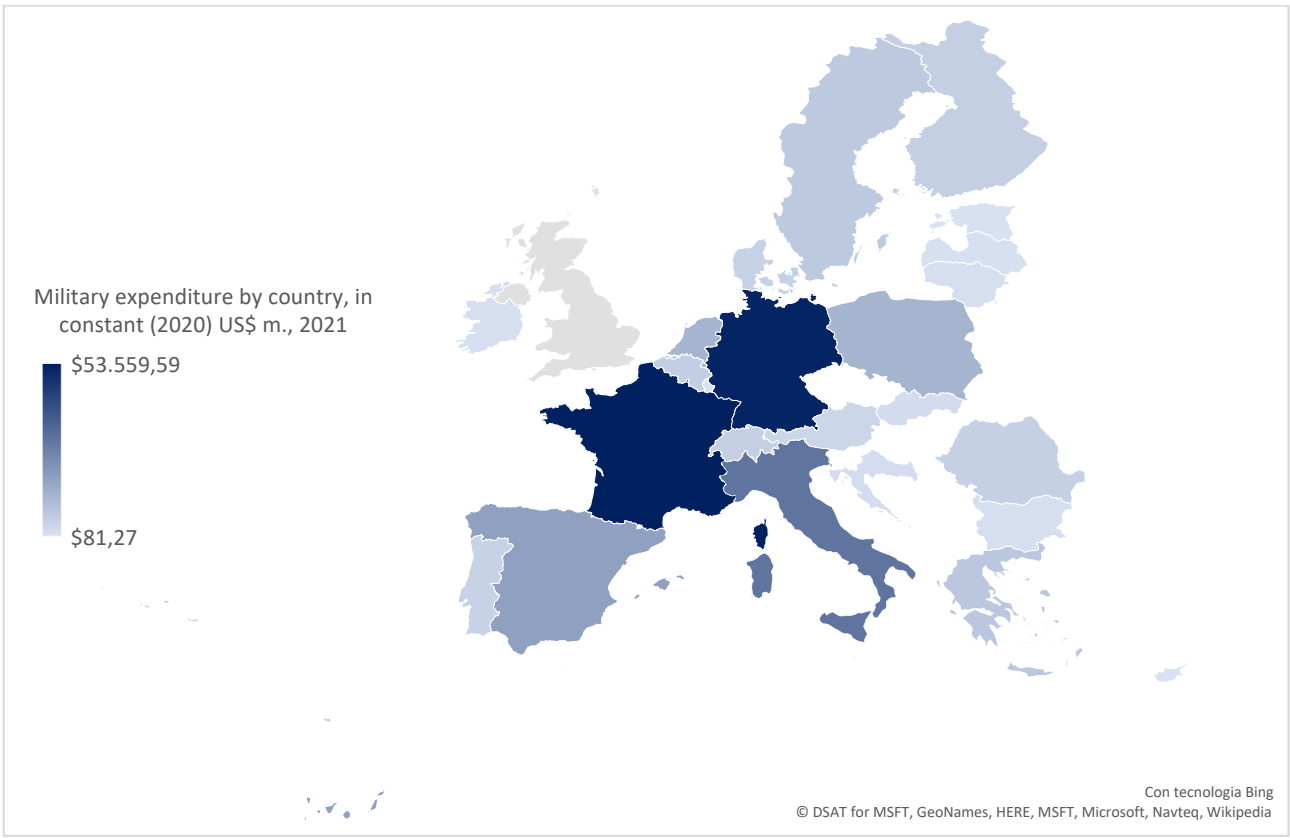

Figure 2 - Distribution of military expenditure in European Union.

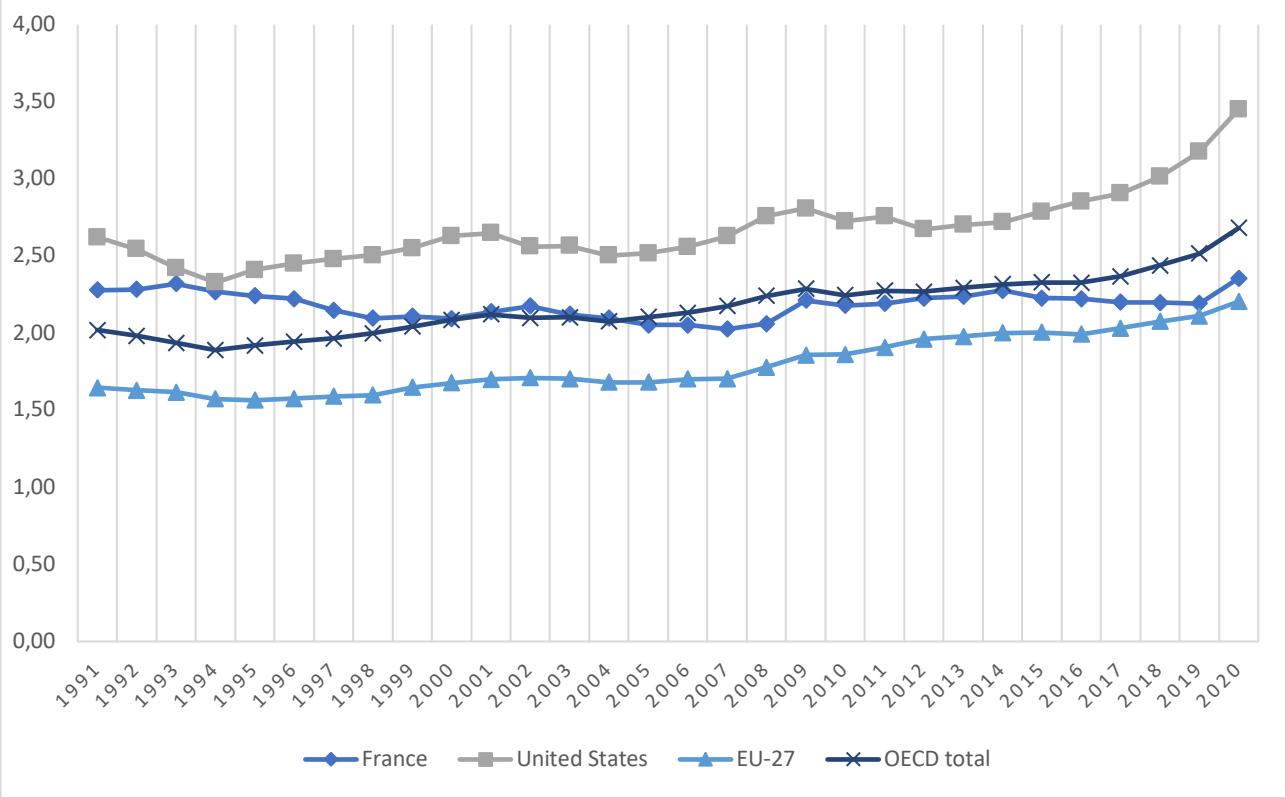

Figure 3 - GERD as percentage of GDP from 1980 to 2018 in OECD countries, U.S., European Union, and France.

The World military burden (i.e., military expenditure as share of GDP[4]) in 2020 is on average 1,86%, as registered in SIPRI Military Expenditure Database[5]. More the 35% of the countries shows values higher than the average and the highest one is the 7,34% of Oman, followed by Kuwait (6,79%), Saudi Arabia (6,59%), Algeria (5,59%), Azerbaijan (5,27%) and Israel (5,17%). So that, in these countries the Government has a great commitment in Defence. The world map in the Figure 1 shows the military expenditure in each country related to the total military expenditure in 2018, as registered in SIPRI Military Expenditure Database. U.S. are the largest spender in the world, whose spending is about 770 billion dollars, the 36% of the global

[4] As explained in the table of data "Military expenditure (% of GDP)" in World Bank [World Bank (2020). *Military expenditure (% of GDP)* [database]. Retrieved from https://data.worldbank.org/indicator/MS.MIL.XPND.GD.ZS]:
"Military expenditures data from SIPRI are derived from the NATO definition, which includes all current and capital expenditures on the armed forces, including peacekeeping forces; defense ministries and other government agencies engaged in defense projects; paramilitary forces, if these are judged to be trained and equipped for military operations; and military space activities. Such expenditures include military and civil personnel, including retirement pensions of military personnel and social services for personnel; operation and maintenance; procurement; military research and development; and military aid (in the military expenditures of the donor country). Excluded are civil defense and current expenditures for previous military activities, such as for veterans' benefits, demobilization, conversion, and destruction of weapons. This definition cannot be applied for all countries, however, since that would require much more detailed information than is available about what is included in military budgets and off-budget military expenditure items. (For example, military budgets might or might not cover civil defense, reserves and auxiliary forces, police and paramilitary forces, dual-purpose forces such as military and civilian police, military grants in kind, pensions for military personnel, and social security contributions paid by one part of government to another.)"
The data of World Bank repositories derives from SIPRI repositories, but in the former the aggregated data (i.e. for EU and World) are already computed.
It specifies that SIPRI is an independent international institute dedicated to research into conflict, armaments, arms control and disarmament, established in 1966. SIPRI provides data, analysis and recommendations, based on open sources.

[5] Data retrieved from SIPRI repositories, available at: https://www.sipri.org/databases/milex , accessed May 2022.

expenditure; so that this country has a dominant position in the world scene. The second one is China, that has a policy of linking the growth in military spending with the economic growth. Then there are India, Russia, United Kingdom, Japan, Saudi Arabia and France. Europe as geographical region is the third largest spending zone, that contributes for 20% of the global value. That means that combined actions could make Europe more powerful and competitive on the world scene. Four of the world's 15 largest military spenders are in NATO and two of them are in Europe: France (rank 14) and Germany (rank 15). Looking closer at the European level, as reported in Figure 2, the top 5 of the spender Member States (MSs) in 2018 are France, Germany, Italy, Spain, and Netherlands. The trend presented in the Figure 3 can be explained by the conflicts and the events that characterized the historical period considered. In 2001 Twin Towers attack has shaken the situation of apparent international calm, leading to the subsequent war in Iraq in 2003-2011 and the intensification of various conflicts, that have continued up to the present day. These events brought current spending to grow, especially for the United States. The reduction between 2006 and 2008 can be related to the world financial crisis; and finally, from 2014 the tendency is stable increasing.

Analysis of the Defence Industrial Base (DIB)

The public commitment in Defence influences competition and innovation in the DIB. Since the DIB develops, produces and provides goods and services for the Military Department of a State, in each Nation there is a solid group of core contractors and various suppliers at the lower levels of the supply chain (Hartley, K. et al., 2019). As a meaning of example, "the French Defence Technological and Industrial Base (DTIB) is structured around a solid core group of suppliers, consisting of eight top class contractors, engine manufacturers and suppliers: Airbus Group, Arquus, Dassault Aviation, MBDA, Naval Group, Nexter, Safran and Thales. This situation is the result of Government policy decisions dating back to the 1960s and adaptations of industry to its environment" (Hartley, K. et al., 2019). The Government supports its DIB and it is also its main consumer. As a result, the Defence Industry is shaped on the National policy and financial decisions. With the purpose to give evidence of this point, it is possible to analyse the SIPRI TOP 100[6].

Firms in SIPRI TOP 100 can be classified in relation to the main operative sector, i.e., Defence and/or Civil, looking at their Arms Sales (AS) as a percentage of their Total Sales (TS). During the last decades, as presented the Figure 4, most of the major firms in Defence industry are

[6] SIPRI TOP 100 derives from the SIPRI Arms Industry Database (https://www.sipri.org/databases/armsindustry, accessed May 2022), that contains information on arms-producing and military services and is based on data from OECD as well as open sources, such as company annual reports and articles in journals and newspapers. Only companies with operational activities in the field of military goods and services are included, not holding or investment companies. Military research and development (R&D) divisions at academic institutions are also excluded. SIPRI TOP 100 is updated every year since 2002. The ranking is based on the sales of military goods and services to military customers, including both sales for domestic procurement and sales for export.

dedicated to a mix production, indeed the SIPRI TOP 100 includes mainly dual firm than pure firms (which operate only in military business context). Considering the total amount of sales, the arms sales cover the 42% of the total sales of the industry in 2020, the 33% in 2018, and the 18% in 2002, proving a greater activity in civil market.

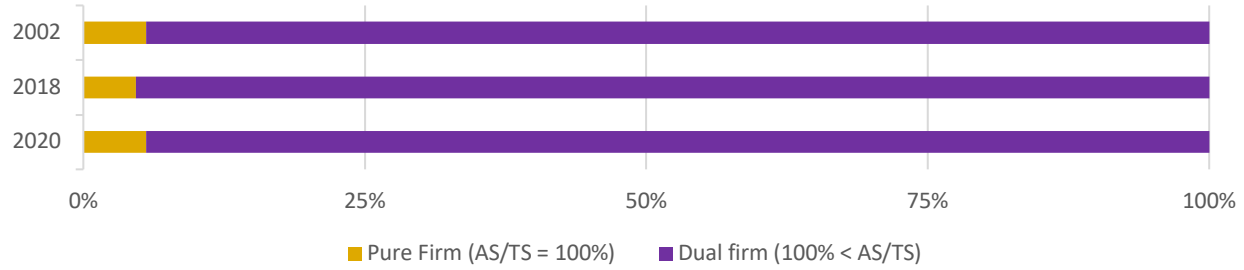

Figure 4 - Comparison between the number of pure firms and dual firms in SIPRI TOP 100 in 2002, 2018, and 2020, as percentage of the total number of firms in SIPRI TOP 100.

The duality tendency is the effect of the reduction of public military expenditure that each Nation experienced after the Cold War. In U.S. "in 1993, Secretary of Defense Aspin and Deputy Secretary Perry concluded that some industrial consolidation was necessary and announced this to executives from major defense companies at a Pentagon dinner. The main message was that the major defense players needed to consolidate to survive, and the Defense Department would facilitate the process by offering financial incentives and advocating consolidations in the event of antitrust challenges. The audience was receptive and as Norman Augustine (Martin Marietta CEO at the time) put it later: «You weren't going to survive unless you were willing to combine. So, there was not much of a choice»" (Hartley, K. et al., 2019).

The numbers of firms within each of the 22 different countries included in SIPRI TOP 100 are presented in the Table 1, which compares values in different years.

	Number of companies in SIPRI Top 100			
Country	**2020**	**2018**	**2017**	**2002**
United States	45	47	49	46
Russia	9	10	10	4
United Kingdom	8	10	9	13
France	6	6	7	9
South Korea	6	3	4	2
Japan	5	6	5	6
China	5	0	0	0
Germany	4	4	4	8
India	3	3	3	3
Israel	3	3	3	5
Italy	2	2	2	5
Trans-European	2	2	2	2

	Number of companies in SIPRI Top 100			
Country	**2020**	**2018**	**2017**	**2002**
Turkey	1	2	2	0
Canada	1	1	0	2
Poland	1	1	1	0
Singapore	1	1	1	1
Spain	1	1	1	2
Sweden	1	1	1	1
Ukraine	1	1	1	0
Norway	1	0	0	1
United Arab Emirates	1	0	0	0
Australia	0	1	1	1
Switzerland	0	1	1	1
Brazil	0	0	1	0

Table 1 - Number of firms per country in SIPRI TOP 100.

The number of the year 2020 confirm the dominant position of the US. In fact, almost half of the firms in SIPRI TOP 100 are American. A total of 5 Chinese firms[7] entered in the SIPRI TOP 100 2021, as well as one of United Arab Emirates. On the contrary, firms from Australia, Switzerland, and Brazil moved to lower position and didn't access this ranking.

The distribution of the market share among firms in SIPRI TOP 100 2021 is shown in Figure 12. Please note that the market share is computed on the total sales, while the ranking in SIPRI TOP 100 consider only the arms sales. In the graph in Figure 5 the names of the firms in the first five position of the SIPRI TOP 100 2021 and of the firms involved in the ASSETs+ Consortium are highlighted.

[7] The inclusion of Chinese companies, for which data is deemed reliable, in the SIPRI database starts from 2015.

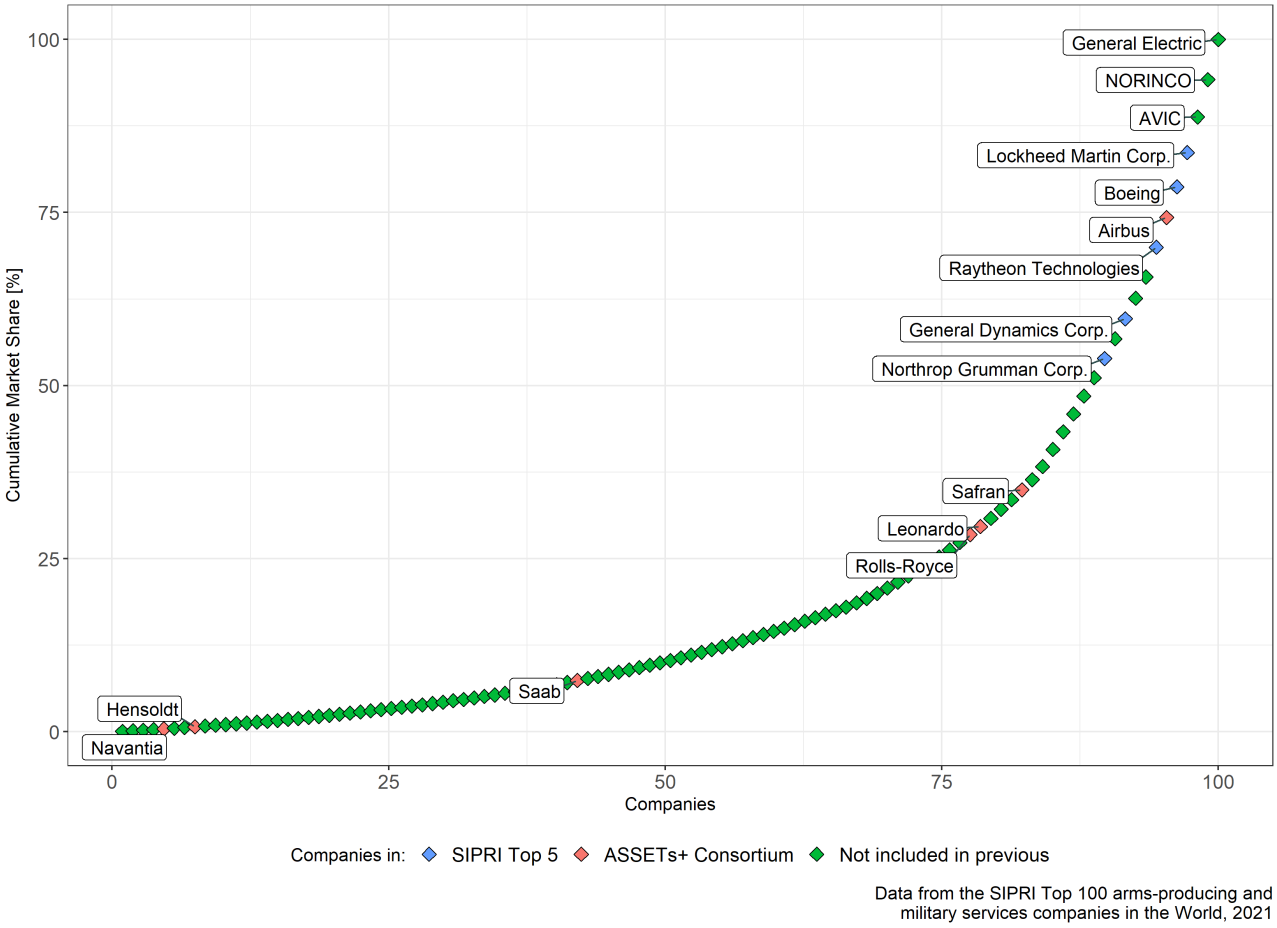

Figure 5 - Distribution of market share among firms in SIPRI TOP 100 2021.

This graph confirms the strong position of American firms: the top 5 firms for arms sales are American (the one in blue in the graph, namely Lockheed Martin Corp., Raytheon Technologies, Boeing, Northrop Grumman Corp., and General Dynamics Corp.); moreover, several American companies hold above the 75% of market share (General Electric, Lockheed Martin Corp., Boeing). Then, Chinese companies held a powerful position in the market (NORINCO, AVIC). There are also Trans-European firms (Airbus Group), which is involved also in the ASSETs+ Consortium. In addition, all the companies of the ASSETs+ Constorium (Leonardo, Safran, Navantia, Rolls-Royce, Hensoldt, Airbus, Saab) are listed in the TOP 100 SIPRI 2021. It is also notable that the companies with the higher market share are all dual firms, proving the increasing relevance of leveraging synergies between Defence and Civil domains. Indeed, the paradigm of unilateral and linear technology transfer from military to civilian, typical of the period from the 1940s to the 1980s, has been overcome by a circular approach in which the multiplicity of actors and purposes pushes an integration (European Commission, 2008).

Description of the project, goals and participants

Over the recent years, the European Commission (EC) has been focusing its attention on the skills mismatches across the European Union (EU), an issue caused by the gap between the fast

industrial evolution brought by Industry 4.0, business digitalisation, artificial intelligence and other Key Enabling Technologies (KET) and the pace in which education and training systems are being able to train and qualify personnel to cope with that evolution.

Technological evolution and innovation and skills mismatches are taking the centre stage on all strategic industrial ecosystems addressed by the Pact for Skills (part of the new European Skills Agenda), launched in November 2020 to foster a joint collaboration amongst those industrial ecosystems towards the recovery of the European Union and its social-economic fabric. One of those ecosystems is the Defence sector, which business processes have to match the technological advancements relying on skilled human resources with the right skills to exploit those technologies in a proper way.

Hence, Defence companies must stay alert on the evolution of the sector to remain competitive on the market. But focusing only on technology is not enough. Human resources need to possess or develop new and high specialized knowledge, skills and competences not only in terms of the technologies but, more relevant, on how the technologies are applied within the domain. This will be possible with training programmes that will align the education system and the labour market in terms of Defence industry's needs and requirements, building up a framework for strategic cooperation in order to support workforce adaptation at regional, national and European levels, and to share knowledge and common practice to promote the digitalisation in the context of Industry 4.0.

In sum, there is an urgency to attract talent and for upskilling and reskilling personnel to match the demands of the Defence sector to ensure it thrives at European level.

The Sector Skill Alliances project *Alliance for Strategic Skills Addressing Emerging Technologies in Defence* (ASSETs+) was designed to reply to this reality. It aspires to design and deliver education and training programmes in the scope of sectoral qualifications frameworks, aiming at Vocational Education and Training (VET) students, undergraduates and graduates from Higher Education (HE) (i.e. between European Qualifications Framework levels 4 and 7), based on innovative pedagogical and methodological approaches, in line with the Pact for Skills' purpose of upskilling and reskilling individuals. The main purpose of those training programmes is to provide these students, undergraduates and graduates with the right set of skills and knowledge that will plug the gap in the existing provision and thereby reduce the skills shortages and mismatches the Defence sector faces, also giving individuals the opportunity of increasing their employability chances and mobility across European countries (i.e. skills portability).

To do so, ASSETs+ is set up to identify the existing and emerging skills needs and occupational (or job) profiles considered a priority in the Defence sector, addressing specific technological domains. These technological domains are gathered in three groups:

- Robotics, Autonomous Systems and Artificial Intelligence (AI);
- C4ISTAR (command, control, communications, computers, information/intelligence, surveillance, target acquisition, reconnaissance);
- Cybersecurity.

To add to the skills needs, priority occupational profiles and technological domains, the training programmes developed in ASSETs+ also address the following topics:

- Digital skills;
- Skills for key-enabling technologies;
- Support for European and regional innovation and smart specialization strategies.

To achieve its purposes, ASSETs+ is comprised of several Work Packages (WPs), described in the following Table 2:

N.	Work package	Short description and main output
1	Technology and skills analysis	Define the Technology Roadmap, which describe the evolution in the technology domain; extract the skill related to the technologies identified, explained in the Skill Blueprint; translate skill needs in job profiles.
2	Education and training	Design the pedagogical approach, test and validate the Education and Training Programme defined.
3	Programmes implementation	Implement a pilot of the plan, in order to review and improve it.
4	Exploitation	Exploit the plan
5	Dissemination and communication	Share the content created developing and implementing a Dissemination and Communication Action Plan
6	Quality assurance and monitoring	Develop and implement Quality Assurance and Monitoring Plan
7	Management	Overall management procedures (monitoring all the project activities and manage communication flow with EACEA and among all the partners)
8	Evaluation	Review and validation to verify they are addressing concrete industrial needs

Table 2 - Work Packages of the ASSETs+ project.

The activities conducted in each WP are interconnected as they ensure that the results of ASSETs+ are fully aligned with the real skills needs of Defence industry, its requirements and technological trends.

ASSETs+: A joint collaboration amongst different sectors

Identifying which competences and skills will have an impact on the future in Defence is important due to this sector's specificities regarding the skills shortages. Some of the extent,

causes, and implications have been already outlined in previous projects, highlighting the need for a project as ASSETs+:

- **Difficulties in forecasting the future demand for skills for Defence** due to the uncertainty related to future levels of public procurement, causing Education and Training (E&T) institutions to be unsure about future demand levels;
- **The low volume of specialist skills required**. Some skills are critically important to the sector but are needed in small volumes. This poses problems for E&T providers, which require programmes to be of an economically viable size;
- **Nationally segmented markets** for skills where 'national eyes only' requirements make it difficult to achieve the economies of scale mentioned above, while **limiting the mobility of skills between members states**;
- **Competition from other sectors** for those with the skills the defence sector needs. This is exacerbated in some countries, where working in defence is considered unattractive;
- **Lack of internal training provision and mentoring programmes** to develop specialist defence skills.

In addition, the current context in which the impact of the global pandemic damaged millions of job across Europe in all industrial ecosystems, provides the project and its main purpose an increased importance. Defence industry companies are in search for short "fit-to-purpose" training programmes that allow employees to upskill or reskill, whether on-site or remotely.

To address these issues, collaboration between different entities and stakeholders from the Defence industry, education and training and social partners is key for the successful research and development of the Defence specific skills. ASSETs+ Consortium fully represents this joint collaboration amongst sectors as it is comprised by 30 partners from 8 different countries, gathered in five specific groups, in addition to two Associated Partners - EUPPORTUNITY (PT) and REPORTBRAIN (UK). Table 3 provides a short description of each group and lists ASSETs+ partners accordingly.

Group	Description	ASSETs+ Partners
Education system	Higher education and scientific institution and structure, public or private, divided into faculties, degree courses, departments and institutes, and in special schools, which has the task of issuing legally recognized academic and professional qualifications, as well	University of Pisa (UNIPI)
		University of Aalborg (AAU)
		Université de Bordeaux (UBX)
		Central Supélec
		Rzeszów University of Technology (PRZ)
		University of Cadiz
		University of Sevilla (UNISEVILLE)

Group	Description	ASSETs+ Partners
	as promoting research, the advancement of science.	Technical University of Madrid
		University Carlos III of Madrid (UCIII)
Vocational Education & Training Providers	Type of education institution specifically designed to prepare people to work (as a technician or in various jobs)	Consaer
		Mercantec
		Aerocampus Aquitaine
		Royal Military Academy
Accreditation, certification, qualification or research foundation	The accreditation, certification, qualification organizations certify the compliance of management systems or products or personnel with specific reference standards and have the authorization to issue a certificate of conformity The research bodies are independent public or private non-profit organizations whose statutory purpose is to carry out research, technological development and dissemination of knowledge.	Fondazione Giacomo Brodolini (FGB)
		Cimea
		European Federation for Welding Joining and Cutting (EWF)
Enterprises	Organization of goods and human capital aimed at satisfying human needs through the production, distribution or consumption of economic goods and services to customers, structured according to a certain corporate organization and administered according to a certain governance by the business management.	Leonardo
		Safran
		Navantia
		Rolls-Royce
		Hensoldt
		Airbus
		Saab
Sectoral organization	Institutions organised nationally and regionally along sectoral lines	Distretto Tecnologico Aerospaziale Della Campania Scarl (DAC)
		Center for Sikkerhedsindustrien i Danmark (CENSEC)
		Groupement des Industries de Construction et Activités Navales (GICAN)
		Fundación Andaluza Para el Desarrollo Aeroespacial (CATEC)
		Asociación de Empresarios del Sector Aeroespacial Andalucía
		Asociación Madrid Plataforma Aeronáutica y del Espacio

Group	Description	ASSETs+ Partners
		Shipyards and Maritime Equipment Association of Europe (SEAEU)

Table 3 - Description of ASSETs+ participants.

All ASSETs+ partners will be working closely during the project's implementation period to ensure a direct connection between Defence industry needs and the results of the project, achieved within each interconnected WP (**Errore. L'origine riferimento non è stata trovata.**

Description of approaches

This section describes the WP1 approaches to analyse technological domains and skills landscape within Defence sector and the WP2 approaches to translate the results of WP1 in Education and Training Programmes for the Defence sector.

The interlinks among these work packages are presented in the scheme of Figure 6:

- The first step (activities in WP1) will set the path of the whole project and it relates to all WPs for central role in developing the main strategy.
- There is a closely connection between WP1, WP2 – *Education and Training* and WP3 – *Programmes Implementation*, indeed training courses developed under WP2 will be design based on WP1 outputs and will be implemented within WP3.
- WP1 interlinks with WP4 - *Exploitation* and WP5 - *Dissemination and communication* as the results will be published and disseminated as best practices to foster their exploitation beyond the project.
- WP1, WP2 and WP3 are connected with WP8 *Evaluation* to ensure that the results are aligned with the needs of the Defence sector.

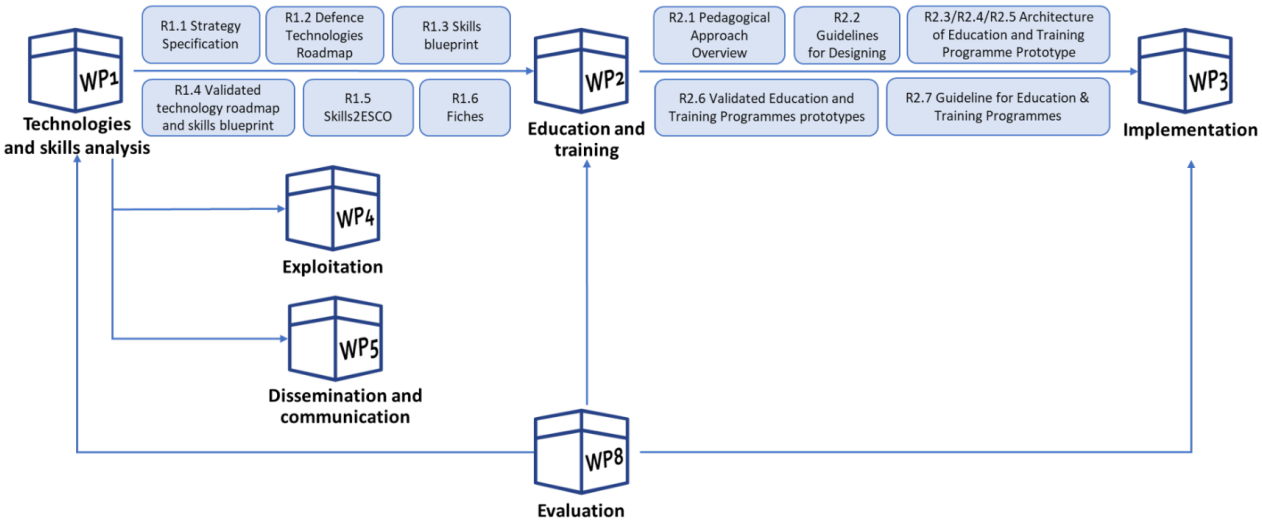

Figure 6 - Connection between WP1 and all other WPs of ASSETs+ Project.

Technologies and Skills Analysis: WP1 approaches to analyse technological domain and skills landscape within Defence sector

According to the fast-technological changes and the emerging of workforce needs, an iterative approach will be carried out (e.g. discovering trends in WP1 - *Technology and skills analysis* and steadily monitoring them, so that it can be possible to take any required action promptly on the remaining WPs). The monitoring and evaluation of the work done in ASSETs+ will be based on quarterly reports (containing activities, reflections, challenges and recommendations for improvements).

WP1 is divided into several tasks:

- **Strategy specification**: develop the methodologies to undertake in this WP and in general in the overall project.
- **Technology mapping**: describe the evolution in various technology domains that could have an impact on Defence and how these ones could be applied, through patents and scientific papers analysis and using algorithms for automatic text analysis, in order to define Technology Roadmap. The main domains and the universities to which research is assigned for each domain are described below.
- **Emerging skill related to selected techs**: understand the link between technologies and skills using Technimetro® (a database of terms and relations related to Industry 4.0, its sources are technical dictionaries, newspapers, scientific articles available from academic sources and open databases on base most cited in association with keyword 4.0) and present the results in the Skill Blueprint.
- **Skills and job profiles validation**: internal validation of results.
- **Skills2ESCO**: interpret the Skill Blueprint to make it compliant for being integrated in the ESCO database (the European multilingual classification of Skills, Competences, Qualifications and Occupations). It is possible to find out existing and new jobs profiles. It will be very useful to better understand what competences and qualifications are needed to upskill the workforce in the Defence sector and so what are the requirement of the training programmes.
- **Fiches**: produce a report consisting in a list of identified relevant Defence related skills programmes and initiatives.

The overall methodology adopted in the WP1 for the analysis of technologies and skills balances standardization and differentiation: it ensures the coherence of results of the three technological domains addressed by the project and allows each team to adopt an approach based on its own expertise, both in technical analysis and in Defence.

Thus, those domains are addressed within the *Technology Mapping* task by partner Universities to perform research, assigned as such:

- **Robotics, Autonomous-Systems and Artificial Intelligence (AI)**: addressed by *Aalborg University* and *Rzeszów University of Technology*;
- **C4ISTAR**: addressed by *Bordeaux University* and *Pisa University*;
- **Cybersecurity**: addressed by *Carlos III University* and *Seville University*.

The three teams are composed by professors, researchers and PhD students who:

- Have specific skills and expertise in the fields of innovation, technologies, design of educational programmes, technology foresight, data science and the extraction of knowledge from deconstructed texts of various kinds (e.g. patents, scientific articles, etc.);
- Have several collaborations in Defence-related projects.

The core of the approaches implemented within WP1 is the **automatic text analysis**, with the purpose to explore a heterogeneous database of resources related to the three technological domains in a quantitative way. The sources of the documents are research institutions, National or International institutions, companies, thematic websites and market surveys.

By consulting different sources:

- Reduce biases: the content of each document may be influenced by various factors (e.g. official documents by National or International institutes may be influenced by political decisions, companies may define the technology domain based on their principal competencies and products and thus may offer only one perspective). Therefore, the variety of the sources makes it possible to balance the biases of each source itself.
- Increase recall: recall is the number of relevant retrieved documents divided by the total number of relevant documents. Having a wide variety of sources increases this variable.
- Validate information: finding the same information in different documents from different sources ensures a higher quality.

Additionally, there is more than one standard of military terminology and various databases of skills available to the public domain, and therefore considered valuable sources as well:

- NATO Terminology database;
- U.S. Department of Defence Dictionary of Military and Associated Terms;
- Glossary in NNEC C2 Maturity Model;
- European Skills, Competences, Qualifications and Occupations (ESCO);
- National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework (NIST SP-800-81).

Moreover, **Technimeter®**, a tool developed by the University of Pisa, has been used in the analysis. It is a database of terms and relations addressing the Industry 4.0 paradigm, available in three languages (Italian, English and German). The sources for this tools are technical dictionaries, newspapers, scientific articles available from academic sources and open databases most cited in association with the 4.0 keyword. It provides hyperlinked text for a set of enabling technologies for Industry 4.0, associated to their definitions and connected between them, and a set of 4.0 skills.

Other methodological approaches used are:

- **Surveys to industrial partners**, to include a practical point of view since the first step of the analysis; in particular 3 surveys have been conducted during the first year of the project;
- **Expert judgment**, to obtain specific information by professionals of the Defence sector, both in academic environment and in industrial one, who acquired domain knowledge thanks to the experience in the specific area.

These methods and sources of information allow to collect relevant information on the "state of play" of the Defence sector in terms of skills needs, priority occupational profiles and technological trends, aspects to be addressed by ASSETs+ as mentioned at the beginning of this document. Hence the relevant role of WP1 to the project and, specifically, to WP2 in what concerns the development of education and training programmes that will cover the skills identified as critical for the sector.

Education and Training: WP2 approaches to connect Education and Training Programmes with Defence sector and EU tools

Generally speaking, and as previously mentioned, WP2 is the link between the relevant information collected in the scope of WP1 and the practical way in which it can be implemented in WP3.

This practical way of implementing WP1 inputs translates into education and training programmes that allow the engagement of VET, undergraduate and graduate students and professionals, the main targets of these programmes. As such, ASSETs+ is contributing to attract new talents to the defence sector and to upskill or reskill its workforce.

To do so, WP2 education and training programmes are designed in line with European Qualifications Framework (EQF) levels 4 and 5, level 6 and level 7, rooted on sectoral and modular approaches, with Competence Units organised in Learning Outcomes, which are written in terms of skills and knowledge to be developed and acquired by participants at the end of the learning process.

In addition to the EQF, also other EU tools are used as reference, such as the *European Skills, Competences, Qualification and Occupations* (ESCO) taxonomy, the *European Credit System for Vocational Education and Training* (ECVET) and the *European Credit Transfer and Accumulation System* (ECTS), thus increasing the programmes' adoption both by VET and HE providers, as well as their transparency and recognition both at national and European levels.

WP2 is comprised of the following tasks:

- **Design of the pedagogical approach and detailed sub-approaches**: identification of the pedagogical approaches dedicated to the Defence sector, to be implemented in each education and training programme.
- **Guidelines for designing Defence sector professional standards and European Defence sector matrix of Learning Outcomes:** allow to ensure and harmonisation of the education and training programmes by providing a framework for using a common structure, irrespectively of the EQF level they address, and their alignment with EU tools for transparency and recognition.
- **Design of education and training programmes' prototypes for VET and for University undergraduates and graduates:** design of education and training programmes addressing EQF levels 4 to 7, addressing specific skills needs of the Defence industry, in line with WP1 results and with the technological domains in which ASSETs+ focuses, to be implemented within WP3.
- **Assessment of design education and training programme prototypes:** recommendations to be considered for ensuring the alignment between the education and training programmes and the pedagogical approaches to be adopted and also the occupational profiles and skills needs identified.
- **Internal validation of the education and training programme prototypes:** validation of the education and training programmes by representatives from Industry, part of the Consortium, to ensure they match the real industrial needs and requirements.

The pedagogical and methodological approaches used for designing and developing the education and training programmes are of high relevance when it comes to ensure they are able to achieve the purpose of replying to real defence skills needs in a harmonised way, in VET and HE contexts.

Thus, it is important to understand these approaches and how they influence the quality and implementation of those programmes.

Design of the pedagogical approach and sub- approaches

By designing a pedagogical approach dedicated to the defense Sector, ASSETs+ academic partners from VET and HE aim at providing a guideline to enable European actors to:

- Create new pedagogical programmes in light of current challenges;
- Adapt existing pedagogical activities;
- Share common and/or best practices;
- Identify and overcome potential barriers.

The selection of pedagogical approaches provides a closer fit to the defense-related skills needed across Europe. The methodology in place in ASSETs+ articulates the different inputs of WP1, on the one hand, and the analysis of WP2 on the other hand, towards classifying and measuring a list of criteria.

These criteria are evaluated for each EQF level to rank and select the best approaches to be adapted in the education and training programmes. The creation of a toolkit of chosen methods caters to the industrial partners' occupational profiles and skills priorities. To achieve this goal, CentraleSupélec and EWF launched a survey amongst ASSETs+ academic partners about their defence-oriented activities to ensure a global coherence and operability of the designed programs potentially all over Europe. Then, the industrial partners have prioritized the skills and job profiles.

The pedagogical approach must include several dimensions:

- The industry’s needs must be at the heart of the training project, considering the recruitment (skills) needs of the Defence sector;
- The current teaching methods of the different ASSETS+ partners;
- The perception of the students and the relationship between them and trainers (to place the student at the centre of the learning process and the trainer as guide of that process);
- The unity of the group of European professors around one outstanding project, aware of the European challenges of skills shortage in the Defence Sector;
- The pedagogical activities required to ensure that students respect a work ethic, enhance an entrepreneurial spirit, foster creativity and innovation, develop intercultural awareness and individual responsibility;
- The strong links with industry.

More precisely, the design approach has to consider:

- Skills required in the future (short, medium, long term);
- Degree of specialization;
- Classification of job profiles expected for initial or continuous training;
- Categorization of the skills (transversal, technical, Defense-related);
- Positioning as EQF according of the nature of the skills and the constraints of demand from labour market/industry.

Once again, the methodology focuses on an iterative process to ensure a continuous dialog between industry and academia partners/sectors. By giving more visibility to the students and concentrating the efforts on a good set of skills, the inadequacy between new skills, upskilling, reskilling and current skills provided can be reduced.

Due to defence sector' s specificity and the local/European dimensions, the pedagogical framework has to be based on:

a. *Multidisciplinary and project-based curriculum*

The orientation of the pedagogical activities has to be problem-based and client-need-oriented. It requires a robust multidisciplinary approach and it mixes different domains such as fundamental, applied, and social sciences. The choice of a "quasi-real" scale for the project-based activities is an excellent way to set up a permanent dialogue with the industrial partners. In parallel, a skill-based focus is emphasized to develop and monitor skills and abilities.

b. *Skills-based approach: knowledge acquisition and skills development, which enables to:*

- Make training more concrete;
- Integrate cross-disciplines according to transdisciplinary objectives;
- Organize teaching based on student learning.

The skills-based approach should guide the selection of ASSETs+ pedagogical activities:

- A high-level knowledge base, according to the standard of the EQF level addressed by each education and training programme, acquired through teachings and for some EQF level via contact with research activities;
- Several experiences throughout confrontation to the business case.

Cross-disciplinary logic is thus in line with focusing learning on complex situations that cannot be addressed separately to develop skills that will enable students to be better equipped facing future situations that they could encounter once in the workforce.

The definition of a skills framework enables to accurately formulate what is expected from students at different steps of their curriculum. Particular importance is given to consistency and continuity in competencies among the diverse teachings. Students demonstrate skills when they know how to act effectively and appropriately in a given situation. This skills-based approach focuses on the students' ability to use what they have learned at the school in new and complex tasks and situations.

Furthermore, common definitions promote a similar background to the design of programmes:

- Definition of a competency: A competency is a set of general and specific knowledge, know-how, and life skills used to solve a problem. Performing a task should not be understood restrictively but as to move from the current situation to a targeted one, using appropriate operations.
- Definition of knowledge: Knowledge constitutes the learning foundation to which the school gives utmost importance continually. However, the skills-based approach aims to go beyond: students should learn how to use and apply knowledge in new situations.

c. *Assessment and feedback*

Assessments are two-fold:

- Evaluation of the knowledge and know-how based on examinations, reports and concrete outputs;
- Evaluation of skills based on the observation of students.

The feedback system from the students, pedagogical actors and industries has the advantage to constantly adapt the content and ensure attractivity both for the students and to the companies.

Guidelines for designing Defence sector professional standards

This guideline is of high importance to the design of the education and training programmes in ASSETs+ as it defines the framework in which they are structured and connected to the above-mentioned EU tools, whilst ensuring a coherent use of methodologies that will increase the programmes' responsiveness to the European Qualification System and their replication by VET and HE providers at national and European levels (connected to the exploitation of the programmes).

Therefore, the document defines the methodology for designing the education and training programmes for all EQF levels and recommendations for their implementation, in line with the modular approach used by EWF in its International Additive Manufacturing Qualification System - IAMQS (recognised by Cedefop (2008, 2017) as best practice and aligned with current education practices), strongly aligned with Industrial skills needs and requirements (sectoral approach) and supported by a robust and transparent Quality Assurance System, also in practice for the implementation of ASSETs+ education and training programmes/qualifications.

The modular approach allows all training programmes/qualifications to address the job profiles and skills needs identified in WP1 through Competence Units (CUs), which are modules of qualifications consisting of a coherent set of skills and knowledge organised in Learning Outcomes (LOs), written in line the EQF level addressed by the given training programme/qualification. The LOs are statements of what a learner is expected to know, understand and demonstrate at the end of a learning process, in line with the change of paradigm

in education and training, in which the learners have an active role in their own learning process and are trained/qualified to make use of those skills and knowledge in the scope of their professions.

This approach offers education and training providers the flexibility to implement the training programmes in accordance with their own resources (human and/or material) and provides learners (i.e. VET students and HE undergraduate and graduate students, or professionals seeking for upskilling or reskilling opportunities) the flexibility to attend the CUs/qualifications in accordance with their own needs and availability.

Moreover, the guideline also offers the needed information on EU tools to ensure the correct allocation of ECVET and ECTS points to each education and training programme, depending on whether it is applied to VET or HE, respectively, thus contributing for the portability of skills across Europe through mobility.

Given the upskilling and reskilling purpose of these programmes, this guideline also provides valuable insights for the implementation of a Recognition of Prior Learning (RPL) process. Thus, it describes the importance of the validation of non-formal and informal learning for individuals already working, with an extensive experience in their own professions, but are not duly qualified, to have access to education and training programmes. Hence, the rules and procedures for the implementation of a RPL scheme in the scope of ASSETs+ are also provided, describing the required steps to validate individuals' prior learning and to issue partial or diplomas, in accordance with the results of that validation.

Overall, the document underlines the importance of each education and training programme designed and developed in the project to integrate the following dimensions:

- A pedagogy approach oriented to match the needs arising from complex systems such as the ones identified in WP1;
- A multidisciplinary and project-based curriculum, able to foster the development of relevant practical, technological and transversal skills and knowledge for the Defence sector, providing learners the possibility to successfully enter directly into the labour market;
- A specific assessment, tailored to the identified LOs for each CU, designed to be implemented in and harmonised way (i.e. learners are assessed through the same assessment tools and procedures, which ensures they acquire the same set of skills and knowledges, irrespectively of the country or training provider), which can only be ensured by a strong quality assurance system.

Also, the guideline stress the importance of paying special attention to the upskilling and reskilling activities in accordance with the EQF levels of the training programmes and given the

priorities the Defence sector identified on WP1, validated by ASSETs+ industrial partners and external experts connected to industry.

Hence, the iteration process that is a characteristic of the methodology implemented in ASSETs+ and its WPs is also applied to WP2 and its respective tasks.

Body of Knowledge

A Body of Knowledge (BOK) is the ontology of concepts, terms and activities that make up a professional domain, as typically defined by the relevant learned society or professional association.

The ASSETs+ Body of Knowledge (BOK) is one of the main outputs of the project, that will map all the relevant competences needed for defence practitioners with respect to the technological scope of the project - Robotics, autonomous systems, artificial intelligence and C4ISTAR and cybersecurity, and will be a guidance document for the European Defence Sector. The objective of ASSETS+ BOK is not only to provide a detailed analysis of the knowledge required by any person working for or on behalf of Defence Sector, but also will be the basis for the design of the educational activities (WP2) to apply in the ASSETS+ project. The ASSETS+ BOK is based on the Technology roadmap (R1.2) and on the Skill Blueprint (R1.3). Also, the Technimeter® (a tool of developed by the University of Pisa that maps skills) will be used to dynamically map job profiles and skills of the defence sector and update the BOK, assuring that the BOK will keep itself updated during and after the project. In this way the BOK will be a reference also for future courses outside of the present project.

Concepts and Conceptual Map

The ASSETS+ project aims at creating a strategy to up-skill defence students and professionals, including the identification and standardization of job profiles related to the technologies identified in this project. So, the topics explored in the ASSETs+ project are:

- the **Defence industry**, with reference on the industrial needs within the Defence sector related to the emerging trends in the domains under analysis (i.e., robotics, artificial intelligence, autonomous systems; C4ISTAR, and cybersecurity),
- and the **education and training programmes** for the actual and future workforce within the Defence sector.

These topics relate each other because evolutions in industry produces changes in labour market needs and so it calls for an upgrade in the field of education, to design programs aligned with the skills and knowledge required in labour market. This relation is briefly explained in the Figure 7 - Connection between industry and education..

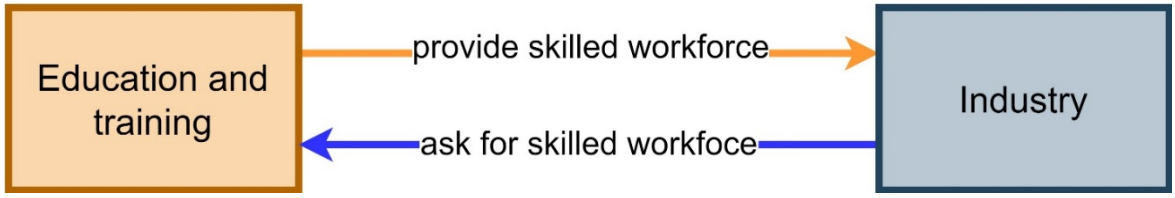

Figure 7 - Connection between industry and education.

With the purpose to explore in deeper this connection, a conceptual map has been developed and presented at the EDUCON2022 – IEEE Global Engineering Education Conference[8].

This conceptual map presents the relations among the building blocks of education and industry, providing a framework to support the exploitation of NLP techniques in the curriculum design process (Spada et al., 2022). The map and the definitions of the concepts from the cited work are introduced in Figure 8 and reported respectively in Figure 9 and Table 4.

The map is built around 3 main elements, namely Education and training activities, People and Industry, which group the concepts. The arrows in blue, yellow and pink depict the main relations among these elements, here summarized:

- Current and future workers acquire their expertise with education and working activities to fulfill labour market demands (pink arrows).
- New trends in labour market requires an update of the skills set, and so new education programs aligned with labour market needs (blue arrows).
- The new education and training programs issue the requried qualification and strenght the personal background of workforce (yellow arrows).

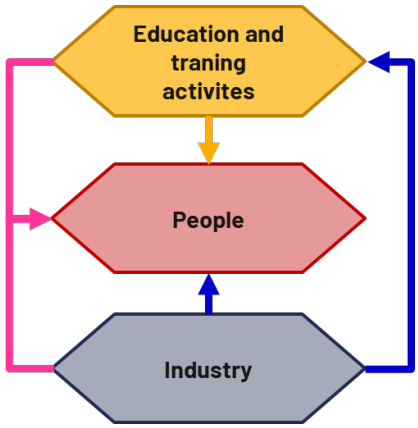

Figure 8 - Scheme of relations reported in the conceptual map.

[8] Additional information on the Conference is available here: http://educon-conference.org/ . Details about ASSETs+ participation are reported in ASSETs+ website here: https://assets-plus.eu/assets-has-participated-in-the-educon2022-conference/ .

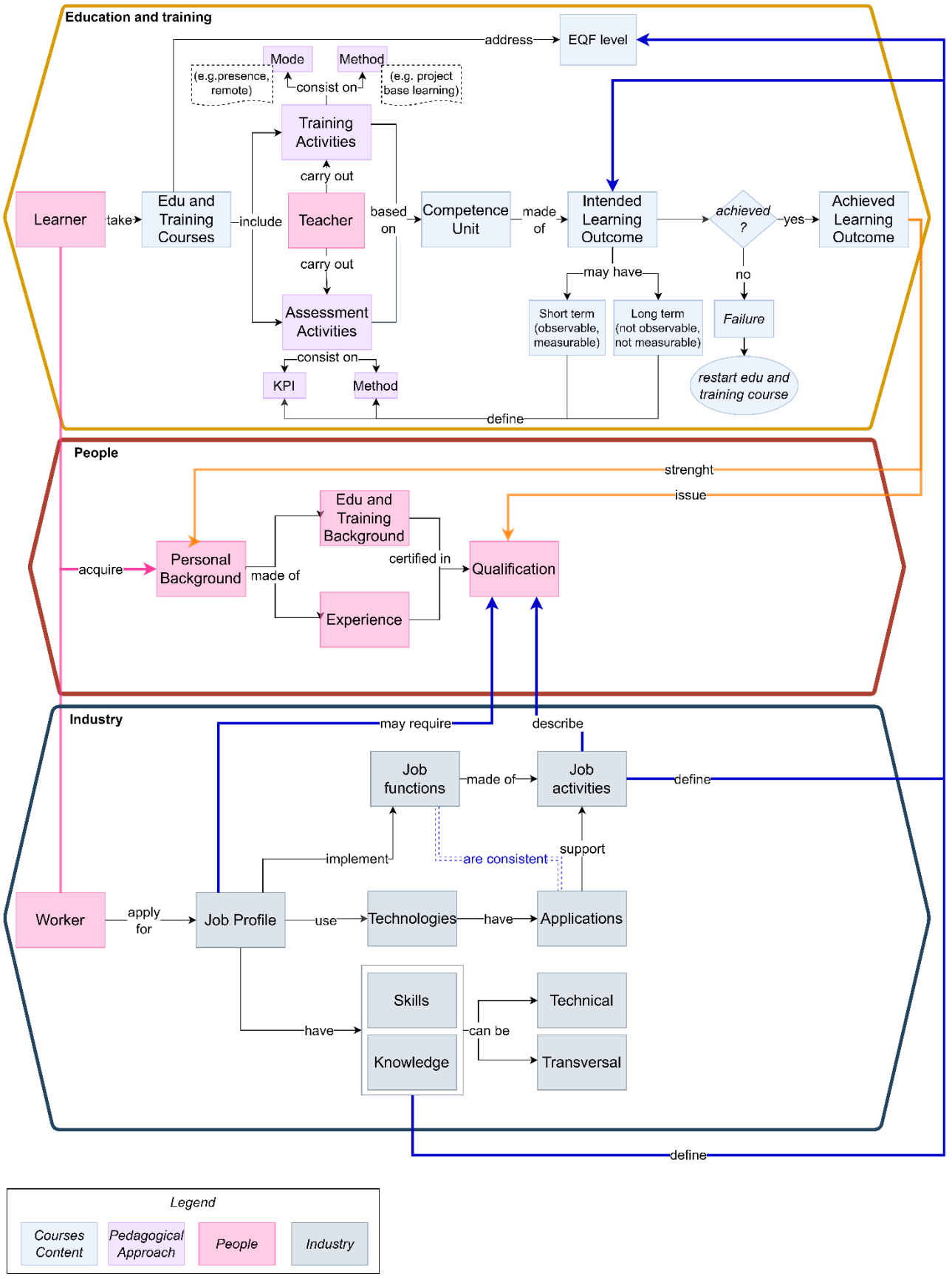

Figure 9 - Conceptual map (Spada et al., 2022).

Entity	Area	Definition
Technology	Industry	A technology is a technical system with technical/engineering content, created by humans as the result of the application of technical scientific knowledge; the systems are designed to be used for a specific purpose, for performing an intended task and for solving a practical problem.
Application	Industry	The act of use something for a purpose.
Competence	Industry	The competence includes the skills, i.e., characteristics of every user to perform an action, where the user is a person who uses a product, a machine, or a service; and the knowledge: refer to a theoretical or practical understanding of a subject. Moreover the competencies can be: • Technical: this category is related to the competences required to correctly exploit a certain technology within a given defence application, aka hard skills; • Transversal: this category includes competencies relevant to a broad range of occupations and economic sectors, they are the cornerstone for the personal development of a person, aka soft skills.
Job profiles	Industry	Description of tasks, duties and responsibility to perform a job; it may also include the qualifications needed for a given role, as well as information about the equipment, tools and work aids used, working conditions, physical demands, and a salary range.
Qualification	Industry Education	It is the formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards. It includes a general description of a professional profile, the set of functions carried out and the list of activities necessary to comply with the job functions. It is related to the required skills and knowledge to perform the job activities. It can be a diploma or any other similar certificate awarded by an Institutional body for the completion of the learning process. It certifies the owned competencies by the learners.
Audience (users)	Industry Education	The audience refers to the people involved, and so on one hand the users of the education and training programmes are the actual and future workforce, i.e., the learners and the workers, and on the other hand the providers of the courses are the teachers.
Intended Learning Outcome (ILO)	Education	The ILOs derive from Bloom's taxonomy and define what a learner is expected to be able to demonstrate after the completion of a learning process, either formal, non-formal or informal. A set of ILOs forms a Competence Unit (CU), that can be defined as a module of the contents of the designed programmes. The ILO describes the set of general and specific knowledge, know-how, and skills used to solve a problem and to perform the tasks of a given occupation.

Entity	Area	Definition
Proficiency level	Education	Each course addresses a certain proficiency level, that is the degree of specialization needed to enable the desired potential of the learner within a given professional position. It refers to the European Qualifications Framework (EQF), a common European reference framework which provides several levels of expertise (EQF levels) required to perform a job.
Pedagogical approach	Education	The pedagogical approach is the approach to teaching. It is the theory and practice of learning. It is the study of how knowledge and skills are imparted in an educational context, and it considers the interactions that take place during learning. It includes both the teaching activities to deliver the ILOs to students and the assessment activities to evaluate the Achieved LOs of students. The pedagogical approach adopted by teachers shapes their actions, judgments, and other teaching strategies by taking into consideration theories of learning, understandings of students and their needs, and the backgrounds and interests of individual students.
Recognition of prior learning	Education	The recognition of prior learning refers to the process in which an Institutional body evaluates skills and knowledge acquired outside a specific learning context for the purpose of determining the individual's standing with respect to standards of competencies or learning outcomes. In fact, during their lives, people are continuously learning, whether in formal, non-formal (e.g., community-based education courses) or informal (e.g., experiences acquired by contacting with others) contexts. Therefore, knowledge and skills of people do not depend just on formal training contexts; their personal and professional trajectories also lead to the acquisition of new knowledge, skills and competences and for that reason they must also be recognised, hence the importance of Recognition of Prior Learning (RPL) process. It is the process that allows an individual to recognise skills, knowledge and experiences towards achieving a specific qualification.

Table 4 - Definitions of entities (Spada et al., 2022).

Concepts and Objectives

The concepts described above in Paragraph 2.1 are addressed in the first two work packages of ASSETs+ project. Technologies, applications, and skills are analysed in WP1. The results of this analysis (i.e., R1.2 Technologies Roadmap, R1.3 Skills Blueprint) are used as the mosaic tiles for the design of the education and training courses, addressed in WP2 (i.e., R2.3 – R2.4 – R2.5 Design of Education & Training Programme Prototype for VET, University undergraduates and University graduates).

The very large amount of knowledge produced needs to be handle correctly to appreciate its value. Therefore, the results are summarized in the R4.5 Body of Knowledge to provide an overview of the overall results and so an ontology of the ASSETs+ project. It constitutes a

guidance for the European Defence Sector since it is a detailed breakdown of the knowledge, concepts and relationships of Defence Sector.

A reader can explore in deeper the evolution of technologies in Defence-related applications with the R1.2 Technologies Roadmap. He/she can have a complete overview on the skills landscape with the R1.3 Skills Blueprint. He/she can discover the education and training programmes designed with R2.3 – R2.4 – R2.5 Design of Education & Training Programme Prototype for VET, University undergraduates and University graduates. Finally, he/she can examine the overall perspective with the R4.5 Body of Knowledge.

The above described relations among the ASSETs+ documents are mapped in the Figure 10 - Map of relations among technologies, application, skill and education and training programmes whit reference to the ASSETs+ documents.10, where we can see the following items:

- three circular sectors, which depict a concept (i.e., technologies, applications, or skills),
- one full circle, that represents the education and training programs, the core element of the ASSETs+ project,
- one circular crown, that relates all the concepts,
- each item provides an indication of the ASSETs+ document addressing it.

Workers and students

exploit **technologies** for

Defence **applications**

thanks to the **skills**

acquired in **edu & training**

programmes

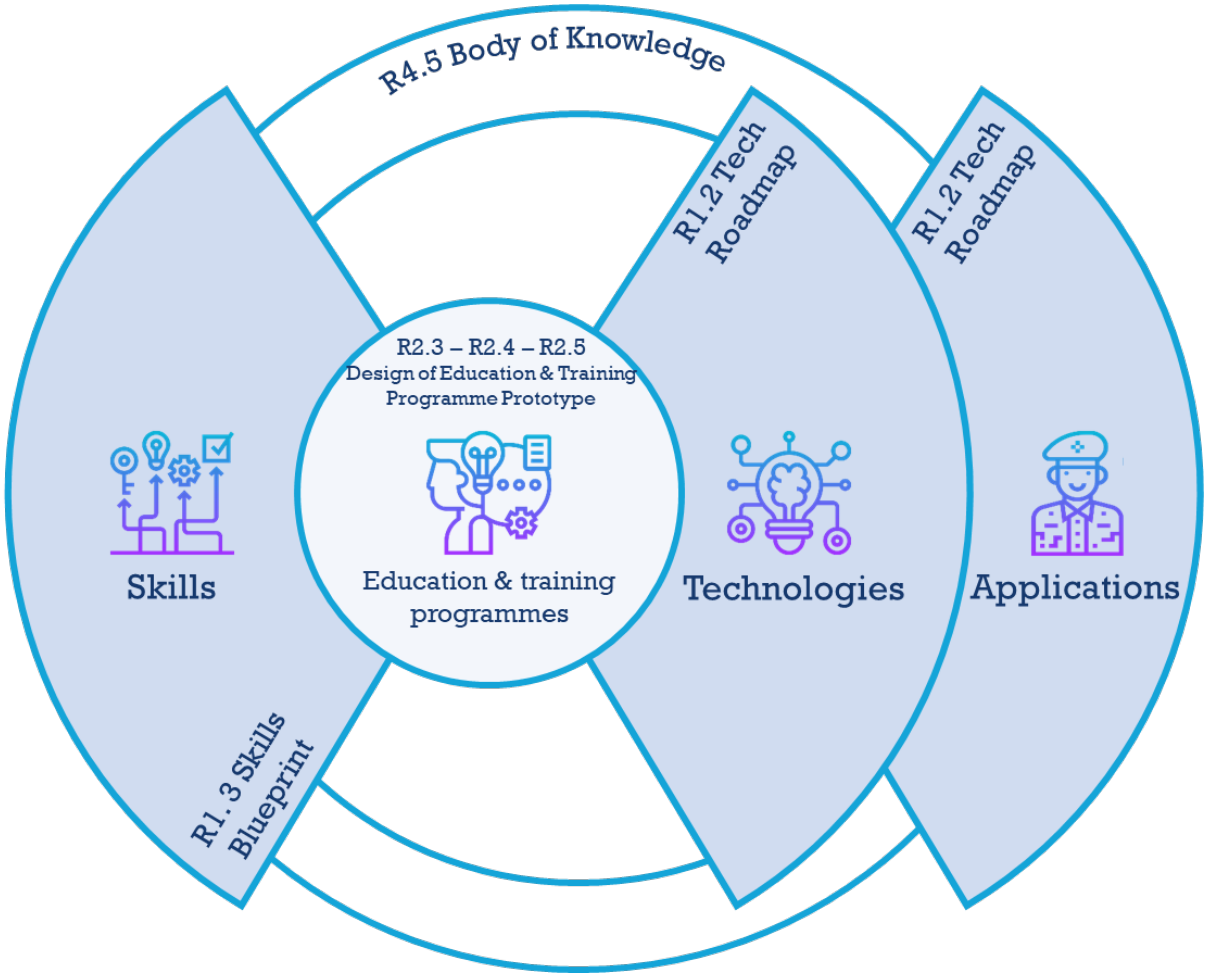

Figure 10 - Map of relations among technologies, application, skill and education and training programmes whit reference to the ASSETs+ documents.

Technological Scope

The data-driven analysis on the evolution in the three technological domains (i.e., Robotics, AI and autonomous systems, C4ISTAR, Cybersecurity) led to the identification of 97 technologies and 59 defence-related application. A strong entanglement among the three technological domains emerged from the analysis. In particular, the C4ISTAR domain includes systems, tools and devices that create Situational Awareness and support decision making, information sharing and data fusion, promoting interoperability and integration during actions. For this reason, C4ISTAR enhances Robotics, AI and autonomous systems domain and needs Cybersecurity to operate properly in the Defence sector. Given its characteristics C4ISTAR is the bonding agent of the domains in ASSETs+. Then, ASSETs+ has held structured brainstorming sessions dedicated to foreseeing the future oriented time-framed relations of technologies & applications, job activities and education & training activities, with technical experts from the Defence Industry belonging to the companies of the ASSETs+ Consortium.

ASSETs+ Consortium proposed a novel framework to map the relations of the technological domains and the area of applications in the Defence industry: the C4AID framework, reported in Figure 11. This is an acronym that stands for "Command, Control, Communication, Cybersecurity, Artificial Intelligence in Defence". This framework can be intended as an ASSETs+ technological evolution of C4ISTAR, given that it includes the emerging technologies addressed in the project in a systemic view within the main Defence areas, namely Factory, Land, Sea, Air, Space and Cyberspace.

C4AID Command Control Communication Cybersecurity Artificial Intelligence Defence (Intelligence, Surveillance, Target Acquisition, Reconnaissance)		**Defence Areas**					
		Factory	Land	Sea	Air	Space	Cyberspace
Technologies	Artificial Intelligence						
	Cybersecurity						
	Robot						
	Autonomous Systems						

Figure 11 - C4AID framework for technologies and defence areas.

The combination of the collected insight led to the identification of 4 main capability areas, intended as cluster of human resources and technical assets, which describe the needs of the

industry in terms of skills, job profiles and technologies for the defence-related applications. These analyses are executed in the tasks T1.2 "Technology mapping" and T1.3 "Emerging skills related to selected techs", then the results are presented in the deliverable R1.2 "Defence Technologies Roadmap" and R1.3 "Skills Blueprint", where the interested readers can find all the details (there documents are available online on the ASSETs+ website at: https://assets-plus.eu/results/Defence-technologies-roadmap-skills-blueprint/).

This paragraph contains for each domain: the definitions, the list of defence related applications with their descriptions, the roadmap of the technologies, skills and job profiles.

Domain definitions

The three technological macro-areas are following defined.

Robotics, artificial intelligence (AI) and autonomous-systems: Robotics, Artificial Intelligence (AI) and autonomous-systems are a combination of technology and cognitive intelligence for simulation, processing of information and knowledge to build capability in a machine to imitate human behaviour and to support people in daily operations (Nagpal, K., n.d.). These technologies can provide multiple options for military applications for a strategic, operational, and tactical level planning in many of the functions. In particular, robotics is mainly focused on to the design, construction and use of robots[9]; Artificial Intelligence concerns with the development of computers able to engage in human-like (Kok, Joost N. et al., 2009), and autonomous systems is related to the systems and devices that receives information through sensors and respond appropriately to carry out its mission all without direct human intervention (Stover, J. A. et al., 1992).

C4ISTAR: C4ISTAR stands for Command, Control, Communication, Computer, Information/Intelligence, Surveillance, Target Acquisition, and Reconnaissance. It indicates systems, structure, processes and all entities involved in missions and in military daily operations (Vassiliou, M. S. et al., 2014). It includes applications related to military operations, sensor systems, as well information technologies and telecommunications, tools and devices that create situational awareness (also known as Common Operational Picture – COP) and support decision making, information sharing and data fusion (Taprest, O., 2017), promoting interoperability and integration during actions in the context of network-centric-warfare (Grant, T. et al., 2005).

Cybersecurity: Cybersecurity plays a critical role in military command and doctrine due to the interconnected systems and devices used in missions and daily operations. In fact, the goal of cybersecurity is to develop and apply protection measures and procedures for the information

[9] Moreover, robotics refers to several scientific domains such as computer science, mathematics, physics, mechanics, mechanical engineering, industrial engineering, electrical engineering, computer engineering, computer science, materials science, manufacturing engineering, automation and control, electronics, cybernetics. (Manseur, R., 1997 and Veruggio, G. et al., 2006)

security. (Efthymiopoulos, M. P., 2019) Cybersecurity involves a great set of techniques and methods for the protection of systems, as well as devices, data and networks, against damages towards:

- availability, the degree to which a system is operable and committable state at the start of a mission;
- integrity, data should remain inalterable at any point;
- authentication, identities should be verified prior to allowing access;
- confidentiality, authorized parties should be the only ones able to access protected resources;
- and non-repudiation, a proof of sender's identity avoids the sender to deny a particular action or transmitted data. (Karaman, M. et al., 2016)

Applications of robotics, AI & autonomous-system domain

The number of applications identified in this domain of knowledge related to defence area is 26. The complete list of the robotics, AI and autonomous-systems applications is the following.

- **Deal with aeronautics and aerospace engineering:** it refers to the study and the application of the science of designing, building, operating aircrafts, and the science of flight. It address several defence technologies such as: military aircrafts, that allow logistic deliveries to forward bases, transporting air transport (cargo and soldiers), and take part in rescue operations during a national disaster; military aviation includes transport, warships and fixed wing aircraft, rotary aircraft (RWA) and unmanned aerial vehicles (UAVs). (Biswas, K., 2019). Technology developed by space science or the aerospace industry for use in spaceflight, satellites, or space exploration. (Wikipedia) The current and future technologies can be connected with the following issues: launch system, reusable launch system, rocket engines, non-rocket space launched, space stations, satellites (remote sensing satellites, global positioning satellites, scientific research satellites, communication satellites, meteorological satellites, solar power satellites), satellites and cyberattack, photonics in space, etc. (Razani, M., 2018)
- **Manage anomaly detection:** refers to the problem of finding patterns in data that do not conform to expected behavior. (Chandola et al., 2009)
- **Manage coverage planning and optimisation**: May refer to planning and optimizing the coverage effects of a particular area or group of things e.g. satellite coverage, artillery coverage, sensor coverage. (Longman dictionary and Cortes, J. et al., 2004)
- **Develop combat simulation**: Representations of military operations using gaming and calculation, with or without man-in-the-loop for training, analysis, and research. (Robinson et al., 1984)
- **Ensure cyber resilience:** the ability to continuously deliver the intended outcome despite adverse cyber events. (Björck, F. et al., 2015)

- **Deal with cyber security:** handle the body of technologies, processes, practices and response and mitigation measures designed to protect networks, computers, programs and data from attack, damage or unauthorized access so as to ensure confidentiality, integrity and availability. (Public Safety Canada. 2010 and Craigen, D. et al. 2014)
- **Deal with fighter aircrafts engineering**: military vehicle (plane) provide control over the necessary airspace by driving away or destroying an enemy aircraft. (Encyclopedia Britannica) Important applications here are designing, manufacturing, maintenance, reliability, safety.
- **Deal with land armours engineering**: an armored motor vehicle, usually armed with a cannon or machine guns. The main purpose of most armored cars was reconnaissance, less often combat. (Medlin, R. C., 2001). Important applications here are designing, manufacturing, testing, endurance, durability.
- **Deal with military vehicle engineering:** industry that makes products from raw materials by the use of manual labour or machinery and that is usually carried out systematically with a division of labour. In a more limited sense, manufacturing denotes the fabrication or assembly of components into finished products on a fairly large scale. (Harris, Charles E. et al., 2002 and Britannica) The applications connected with military vehicles manufacturing, additional to manufacturing processes of other kind of products, are among others: data protection, special contracts with suppliers, concessions.
- **Deal with missile engineering**: missiles are objects (such as a weapon) thrown or projected usually so as to strike something at a distance. (Merriam-Webster's dictionary) Important applications here are missile designing, missile manufacturing, missile testing, missile reliability, missile control.
- **Manage mission control**: Manage mission control tools to support mission execution, supervising and adjusting mission parameters using human-machine interface. (J. Alves et al., 2006)
- **Manage mission planning**: Mission planning is a process of mission analysis that details required courses of action by specifying a sequence of tasks, defining resource-to-task allocation, and a timeline for all task activities. (G. M. Levchuk, 2002)
- **Deal with naval engineering**: fleet of ships whose task is to defend the interests of the state in maritime areas. In naval warfare, military aircraft play a significant role to detect and neutralize submarines and warships to keep the seacoast free from enemy attack. (Biswas, K., 2019) Important applications here are, among others: ships and equipment designing, manufacturing, communication, cybersecurity, object detection, fully integrating manned/unmanned systems, surface forces, submarine forces, naval aviation, naval special forces, coastal defence forces, planning, execution, and sustainment of major naval/joint operations and maritime/littoral campaigns, steam and nuclear propulsion, internal combustion engine, submarine, airplane, mine, torpedo and

missiles, undersea cable, wireless telegraphy, radio. (Smith, M. B., 2014; Haico te Kulve, H. et al., 2010 and Andrew Forbes 2015)

- **Perform path planning:** In robotics, path planning concerns problems such as how to move a robot from one point to another point. In artificial intelligence, path planning means a search for a sequence of logical actions that transform an initial robot state into a desired goal state. (DuchoĖ, František, et al., 2014)
- **Run reconnaissance**: Plan and implement an exploratory survey to gain information in the enemy territory. (Merriam-Webster's dictionary)
- **Manage resource assignment**: Plan and implement an optimization process of assigning items from one category with certain attributes to the other items from other categories in order to achieve desired results. (Burkard et al., 2012 and Munkres, J., 1957)
- **Manage routing**: Plan and implement an optimization process of assigning the specific routes from starting point to the desired destination while satisfying a set of requirements. It can be applied to vehicles and data in telecommunication networks. (Tarantilis C., 2008 and Ash, Gerald, 1997)
- **Manage scheduling**: Plan and implement a procedural planning that indicates the time and sequence of each operation. It deals with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives. (Merriam-Webster's dictionary and Michael Pinedo, 2002)
- **Search and rescue**: Perform operations for a recovery of isolated personnel who are specifically designated as hostages or in danger. (Merriam-Webster's dictionary)
- **Deal with submarine engineering**: it refers to the study of the machines, systems, vehicles working under the water surface. Underwater vision systems (used in autonomous underwater vehicles) enable positioning and maintenance of stations, navigation and mosaic image of the seabed. Underwater vehicles include autonomous underwater vehicles (AUV), underwater gliders, unmanned underwater vehicles (UUV). (Nagahdaripour, S. et al., 1998; Horgan, J. et al., 2006 and Bogue, R., 2015)
- **Surveillance**: The systematic observation of aerospace, cyberspace, surface, or subsurface areas, places, persons, or things by visual, aural, electronic, photographic, or other means. (DOD Dictionary of Military and Associated Terms)
- **Target tracking**: The target tracking objective is to collect sensor data from a field of view containing one or more potential targets of interest and to then partition the sensor data into sets of observations, or tracks, that are produced by the same sources. Once tracks are formed and confirmed (so that background and other false targets are reduced), the number of targets can be estimated and quantities, such as target velocity, future predicted position, and target classification characteristics, can be computed for each track. (Blackman, S. et al., 1992)

- **Trajectory tracking:** the problem of stabilizing the state, or an output function of the state, to a desired reference value, possibly time varying. So defined the trajectory tracking problem incorporates most of the problems addressed in the control literature: output feedback regulation, asymptotic stabilization of a fixed-point and, more generally, of admissible non-stationary trajectories, practical stabilization of general trajectories. (Morin et al., 2004)
- **Deal with satellites engineering**: it refers to the study of any manufactured object or vehicle intended to orbit the earth, the moon, or another celestial body. They enable tele transmission of radio and television signals between ground stations. Currently, satellite operations are performed by robots that are semi-automatic and require monitoring and control by ground teams. In the future, it is planned to use unmanned orbital robots. (Barba, E. et al., 2020; García, J. et al., 2019 and Merriam-Webster's dictionary)
- **Deal with weapons engineering**: it refers to the application of engineering studies to any tools used to injure, defeat, or destroy an enemy / opponent. In the military industry, machine guns, machine pistols etc. and biological, chemical and nuclear weapons can be distinguished. (Swyter, H., 1970) Important issues here are weapon designing, weapon manufacturing, weapon testing, weapon reliability.

Applications of C4ISTAR domain

The identified potential defence applications related to C4ISTAR domain are 25. The list of the C4ISTAR applications with a brief description is the following.

- **Analyse data**: Data Analysis is a process of inspecting, cleansing, transforming and modeling data with the goal of discovering useful information, informing conclusion and supporting decision-making. (Xia, B. S. et al., 2015)
- **Collect image information with sensors**: Imagery is the collection by visual photography, infrared sensors, lasers, electro optics and radar sensors such as synthetic aperture radar wherein images of objects are reproduced optically or electronically on film, electronic display devices or other media. (White, F. E., 1991)
- **Combine data**: Combine data refers to the process of extracting exportable data from multiple sources to provide unified view of the set of these data. It is related with the Data Fusion, i.e., a process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete and timely assessments of situations and threats as well as their significance. (White, F. E., 1991)
- **Command and Control**: Command includes the authority and responsibility for effectively using available resources and for planning the employment, organizing, directing, coordinating and controlling military forces for the accomplishment of assigned missions establishing rules and constraints; and monitoring and assessing

the situation and progress. The exercise of these functions requires a lawful authority that a commander in the military service exercises over subordinates by virtue of rank or assignment. (White, F. E., 1991 and Alberts, D. S., 2010) Control refers to structures and processes to manage the mission problem in order to minimize the risk of not achieving a satisfactory solution. The concept embraces: the continuous acquisition, fusion, review, representation, analysis, and assessment of information on the situation; issuing the commander's plan; tasking of forces; operational planning; organizing and maintaining cooperation by all forces and all forms of support. It is related also to exert influence over an entity, process, object or area to establish, maintain or prevent a specific situation or event. (Alberts, D. S., 2010)

- **Communicate with others**: Communication is the transfer of intelligence, knowledge or information according to agreed conventions. (NATOterm)
- **Control something from a distance**: Remote control is a process or a system for controlling something (such as a machine or vehicle) from a distance, by using electrical or radio signals.
- **Create and send message**: Messaging is the process of sending someone a communication in writing, in speech, or by signals.
- **Determine position in a trajectory**: Navigation is the method of determining position, course, direction and distance traveled.
- **Determine position of a target**: Positioning is the process related to determining the position of a vehicle or person on the surface of the Earth. (Tetley, L. et al., 2007)
- **Encript data**: Encryption is the transformation of data, for the purpose of privacy, into an unreadable format until reformatted with a decryption key, so that only authorized individuals can read it. (fieldtechnologiesonline)
- **Make decision**: Decision Making is the process of choosing among several alternative possibilities. (Brockmann, E. N. et al., 2016)
- **Manage and exploit military intelligence**: Intelligence refers collectively to the functions, activities and organizations which are involved in the process of planning, gathering, and analyzing information of potential value to decision makers and to the production of intelligence as defined above. (White, F. E., 1991)
- **Manage logistic**: Logistic is the process of planning and organizing to make sure that resources are in the places where they are needed, so that an activity or a process happens effectively.
- **Monitor the operations**: Monitoring is a continuous assessment of programmes based on early detailed information on the progress or delay of the ongoing assessed activities. (United Nations Development Programme)
- **Plan**: Planning is the establishment of goals, policies, and procedures in deciding how to do something to achieve the desired goal.

- **Process data**: Data Processing is the process to organize data for the analysis. These may involve placing data into rows and columns in a table format for further analysis, such as within a spreadsheet or statistical software. (Schutt, R. 2013) Information processing is the change of information in any manner detectable by an observer. It concerns with gathering, manipulating, storing, retrieving, and classifying recorded information. (Denning, P. J. et al., 2012)
- **Program with a programming language**: Programming is the process of translating the system specifications prepared during the design stage into program code. (Laudon, K. C. et al., 2011)
- **Protect communication**: Authentication is a security measure designed to protect a communication system against acceptance of a fraudulent transmission or simulation by establishing the validity of a transmission, message, or originator. This process is used to identify individuals and verifying their identity and eligibility to receive specific categories of information. (White, F. E., 1991)
- **Realize a specific tasks related to a purpose**: Mission is an important official job that a person or a group of people are sent somewhere to do. It is related to a specific task with which a person or a group is charged.
- **Recognize friendly or hostile object**: Identification is the process of determining the friendly or hostile character of an unknown detected contact. In arms control, the process of determining which nation is responsible for the detected violations of any arms control measure. In combat operations, discrimination between recognizable objects as being friendly or enemy, or the name that belongs to the object as a member of a class. (White, F. E., 1991)
- **Run Reconnaissance**: Reconnaissance is a mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy; or to secure data concerning the meteorological, hydrographic or geographic characteristics of a particular area. Also known as RECCE or RECON. (White, F. E., 1991)
- **Share information with others**: Information Sharing is the act of passing information from one to another.
- **Simulate process**: Simulation is an approximate imitation of the operation of a process or system, that represents its operation over time. (Banks, J. et al., 2001)
- **Surveillance**: Surveillance is the systematic observation of aerospace, surface, subsurface areas, places, persons, or things by visual, electronic, photographic, or other means. (White, F. E., 1991)
- **Target Acquisition**: Target acquisition is the detection, identification and location of a target in sufficient detail to permit the effective employment of weapons. It is related to target analysis, as an examination of potential targets to determine military

importance, priority of attack, and weapons required to obtain a desired level of damage or casualties. (White, F. E., 1991)

Applications of Cybersecurity domain

There are eight (8) applications identified in this domain of knowledge related to defence area. The complete list of the cybersecurity applications is the following.

- **Carry out cyber electronic warfare activities**: Cyber electronic warfare activities merge cyber and electronic warfare in the same context to support, enable, protect, and collect on capabilities operating within the electromagnetic spectrum (EMS), including cyberspace capabilities. (Karamanetal, M., n.d.)
- **Develop cyber operations**: Cyber operations is the cyberspace capabilities whose main purpose is to attain the objectives in or through cyberspace. Cyber Operations can be further classified into Ciber Operation (OCO) and Defensive Operation (DCO). (Karamanetal, M., n.d.)
- **Develop military information support operations**: Military information support operations are the actions specifically concerned with the integrated employment of cyberspace information-related capabilities during military operations, to influence, disrupt, corrupt, or usurp the decision making of adversaries and potential adversaries while protecting friendly forces.
- **Increase Operations Security (OPSEC)**: Operations security is a process to help to identify those actions that can be observed or collected by adversaries, determine indicators that adversaries might obtain and interpret to derive critical information, and, if appropriate, select and execute OPSEC measures that eliminate or reduce risk to an acceptable level. (osti.gov)
- **Perform and design cybersecurity awareness and training activities**: Cyber security awareness and training is the use of training platform to address the cybersecurity weakest link, the user; providing enhanced guidance for conduct and proper use of information technology by military personnel, in order to increase operational efficiency.
- **Protect communications**: Secure communication is used to protect both classified and unclassified traffic on military communications networks, including voice, video, and data. (doi.org)
- **Protect Defense Industrial Base contractors**: Defense industrial base collaboration provides increased assurance to the Defence Department that a DIB contractor can adequately protect contract and controlled information at a level commensurate with the risk, accounting for information flow down to its subcontractors in a multi-tier supply chain. (Cybersecurity maturity model certification)

- **Support Command and Control systems**: Command and control support is the command & control decision support (Intelligence, Surveillance, Target Acquisition, Reconnaissance).

It is worth noting that some of the applications defined above are related to attack missions. Therefore, they will not be pursued to design the educational programmes, considering the scope of our project. However, they are cited in this BoK for the sake of completion.

Technologies, Skills and Job profiles Roadmap

Technologies, skills and job profiles constitute the capabilities to be developed in the strategy for a sustainable HR supply chain for the Defence sector. Following the capability driven approach and elaborating the results of the technologies and skills analysis, the ASSETs+ Consortium identified 4 capability area, so cluster of physical/technical assets and workers who use technologies and applications thanks to their skills. The capability driven approach constits on analysing jointly the technical assets (in the ASSETs+ case, the technologies and their related applications in the defence area) but also on the intangible ones (in the ASSETs+ case, the skills and the job profiles). This approach allows the development of the roadmap with a broader perspective on the needs of the sector.

The capabilities areas can be defined summarizing the functional purpose of the technologies and the related activities of the job profiles involved. The technological capabilities can be summarised with the generic words systems (sets of technologies, humans, methods, and processes). The capabilities areas defined within the scope of ASSETs+ are: Autonomous systems, Cybersecurity systems, Intelligent information systems, and High performance computing systems. As indicated by industrial experts during their consultations, those areas are the ones that are really relevant to the Defence field for the future.

The technological domains of Robotics, Autonomous Systems, AI, Cybersecurity, and C4ISTAR - in analysis in the ASSETs+ project – relate with the above-mentioned areas as follows:

- Robotics, Autonomous Systems and AI is linked to the broader field of Autonomous Systems, addressing devices and digital tools with a certain degree of autonomy in developing the assigned tasks.

- Cybersecurity is linked to Cybersecurity systems, inclusing both the hardware and software to ensure the protection of data and infrastructure.

- C4ISTAR is linked to the Intelligent Information System area for what concern the data and techniques for ensuring situational awareness and to the High-Performance

Computing Systems area for what concern the technical infrastructure needed to manage and elaborate the data flow in the operations.

This broad definition allowed to highlights links and connections among the technological aspects (i.e., technologies and applications) and the intangible elements (i.e., skills and job profiles) of the domains

The capabilities area are following described in details.

1. **Autonomous systems**: The use of autonomous systems and drones has opened new potential scenarios in Defence. These systems enhance the several Defence-related applications, such as reconnaissance, surveillance, and target tracking. For example, drones and similar vehicles can systematically observe space, surface or subsurface, collecting a great amount of information to properly support decision making process and improve situational awareness in daily operations and missions. Human workers and increasingly high-tech components – whether hard or soft – will inevitably interact in Cyber Physical Systems.
2. **Cybersecurity systems**: The duality of physical and digital environment and the increasing digitalization and automation of the processes call for new cybersecurity strategies and approaches are needed to monitor and secure the complex network. A promising area of development will be the integration of AI applications to execute cybersecurity tasks and enable smart decisions providing validation detection engine. Future experts will develop and execute security architecture and procedures to secure the networks and all the embedded systems and integrated components.
3. **Intelligent information systems**: The possibility to collect and exchange a great amount of data nearly in real-time is revolutionizing the approach to knowledge. In the context of Defence, this means increasing the pace of the decision-making cycle. Developing a data strategy and pursuing data and information supremacy will be essential to achieve the goals of a mission. The main challenges are the development of information systems to support daily operation and mission and enhance planning and decision making, and the training of current and future workers who oversee understanding how to deal with the harmonization of the variety of data in high-tech systems that leverage on different Artificial Intelligent and Machine Learning algorithm to enable the potential knowledge behind them.
4. **High performance computing systems**: As said before, data are crucial in the Defence operations and algorithms, and techniques used to gather and share the data among all the operators and the command centres requires a higher computational power. We will need hardware and software infrastructure to process the quantity and the complexity of the information at a reasonable speed.

The technologies, the skills, and the job profiles are distributed in the four capabilities areas in the roadmap developed in the scope of ASSETs+. It is reported in the Figure 12. The detailed insights for each capability areas are presented in R1.2 and R1.3 (available online on the ASSETs+ website at: https://assets-plus.eu/results/Defence-technologies-roadmap-skills-blueprint/). The analysis is integrated with the framework of the European Classification of skills and compenteces (ESCO). Therefore, it is possible to leverage on ESCO repositories to find out the definitions of the skills and job profiles reported in the roadmap.

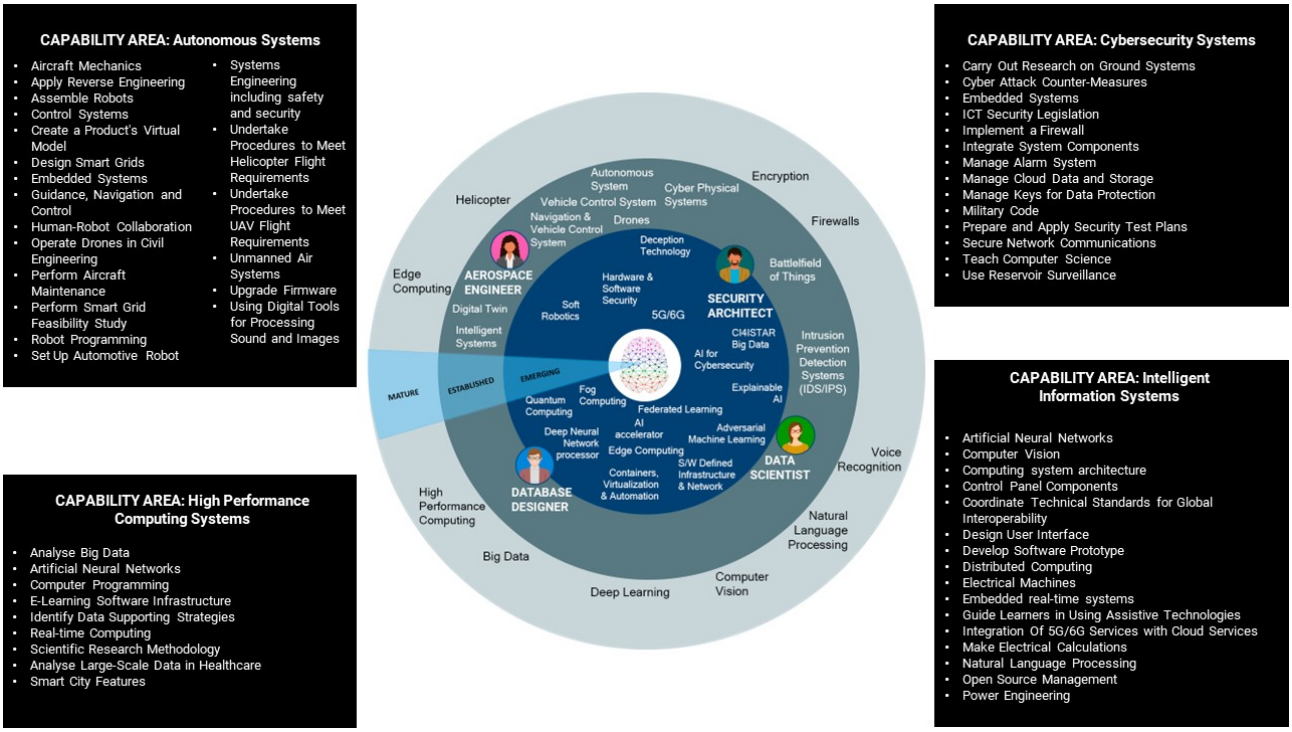

Figure 12 - ASSETs+ roadmap of technologies, skills and job profiles.

Conclusions

The problem facing the European Defence Industry is twofold: (i) it is experiencing difficulty in finding the necessary skills in order to sustain its leadership, competitiveness and sustainability in the medium to long-term; (ii) aging staff and difficulties in engaging and keeping young professionals are preventing the sector from reshaping company capabilities and creating new, attractive job opportunities for talented workers of any age.

ASSETs+ project aspires to build a sustainable human resources supply chain which allows Defence sector companies to innovate by both attracting highly-skilled young workers and upskilling their employees thanks to customised, complementary education & training programmes addressing three main technologies: Robotics, artificial intelligence and autonomous-systems, C4ISTAR, and Cybersecurity aspects related to the first two.

The development of a Defence Body of Knowledge (BOK) with defence-specific topics for the different mentioned technologies is thus a key element for the exploitation strategy of the sector and it is strongly linked with both skills (demand and offer) and qualifications.

The ASSETs+ BOK, presented in this document, can be seen as a guidance document for the European Defence Sector, containing the definition of the relevant concepts. Those topics can be addressed by education and training programmes that are rooted on sectoral and methodological approaches, as well as innovative pedagogical approaches (such as the ones designed and developed in ASSETs+).

ASSETs+ BOK is also intended to be a future reference for any person working for or on behalf of defence sector bodies or organisations. In order to promote this continuous new skills acquisition, development and retention, the BOK will be updated every year.

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