Blending brainstorming with industrial experts and automatic data-driven analysis

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The goal and the approach

The goal of ASSETS+ project is developing a strategy to upskill and reskill students and professionals in Defence sector, starting from identifying and mapping the most important technologies and exploring their impact on skills and human capabilities. The technological focus of the project is on Robotics, Autonomous Systems, Artificial Intelligence (AI), Cybersecurity, and C4ISTAR.

The relation of technology, work and education is generally difficult to investigate, and even more in the Defence sector, as it is at the frontier of innovation and information (both R&D and HR related) are mainly confidential for strategic purpose. We propose the use of qualitative and quantitative methods to handle the complexity of such tasks. We rely on Natural Language Processing (NLP) techniques for big data analysis of technical and scientific documentation; then we look at the trends of technologies and skills in a holistic and future-oriented way, harnessing the expertise of the academic and industrial partners of the ASSETs+ Consortium.

Automatic data-driven analysis

The first step is to map technologies to relevant Defence applications. The approach has a twofold goal: the exploration of each domain to identify the core technologies, their trends and classify them according to their maturity level; and the identification of applications of the technologies, to describe how these are adopted and applied in Defence sector. We outline the technological domain in analysis and further generate a list of technologies and applications collecting sector-specific documents and analysing them using NLP tools and expert revisions. The documents are collected among research institutions, standardization and best practices institutions, companies, thematic websites, and market surveys, with the purpose to have a heterogeneous database of resources.

A data-driven approach allows to automate the process of extracting keywords related to technologies and to defence applications from the collection of documents. The process makes use of lists and regular expressions to detect relevant information in a text corpus, as explained by the authors in [1]. Several documents have been also examined by experts to validate and refine the list of technologies and applications. The identified technologies have been thoroughly analysed with qualitative and quantitative measures, such as maturity level and the abstraction level. Those compute the interest from research and industrial parties, the growth production of new scientific and technical knowledge, indexes widely adopted to evaluate the technologies evolution [2].

The relationship between applications and technologies are then described in a so-called relevance matrix, where each row is a technology, each column is an application, and each cell contains the relevance score that quantifies the importance of each technology for a given defence application. The definition of the relevance score is based on the number of scientific papers containing each pair application-technology. We also used a survey to defence-related industrial organization to gain additional insight on the relevance score.

The second step is to understand the skills demand in the Defence sector related to the selected technologies to help design new educational and training programmes. The current skills landscape has been delineated in terms of 3 categories of skills, namely technical skills, required to correctly exploit a certain technology within a given defence application; defence-related skills, connected to the knowledge, the use and the management of methods and procedures typical of the defence applications; and transversal skills or soft skills that are having an increasing importance in all the industries. We used job posting, industrial surveys, literature analysis, and skills and occupation taxonomy (European Skills, Competences and Occupation Classification, ESCO) to identify skills and job profiles linked to the technologies and applications mapped in the first step, as demonstrated in [3].

The analysis again mixes Natural Language Processing and expert judgment. The relevance of the skills is measured with qualitative and quantitative indicators, namely the degree of specialization, i.e., how important the skill is for the relative job profile in the defence sector, the degree of knowledge, i.e., the required level of a skill for the relative job profile to perform a defence-related job, and the demand from labor market, that indicates how much a skill is required for the given job profile.

We detected and classified 97 technologies, 59 applications, 172 skills, and 181 job profiles, developing a full picture of the actual landscape in the Defence sector, that represents the foundation for building up a comprehensive roadmap to guide the future development of defence-related training courses.

The map reported in the Figure 1 represent the distribution of the technologies among the different domains and their maturity, reported on the horizontal dimension, and abstraction levels, presented on the vertical dimension. It is one of the possible visualizations derived from the automatic data-driven analysis and it has been used as an input for the brainstorming in the second phase.

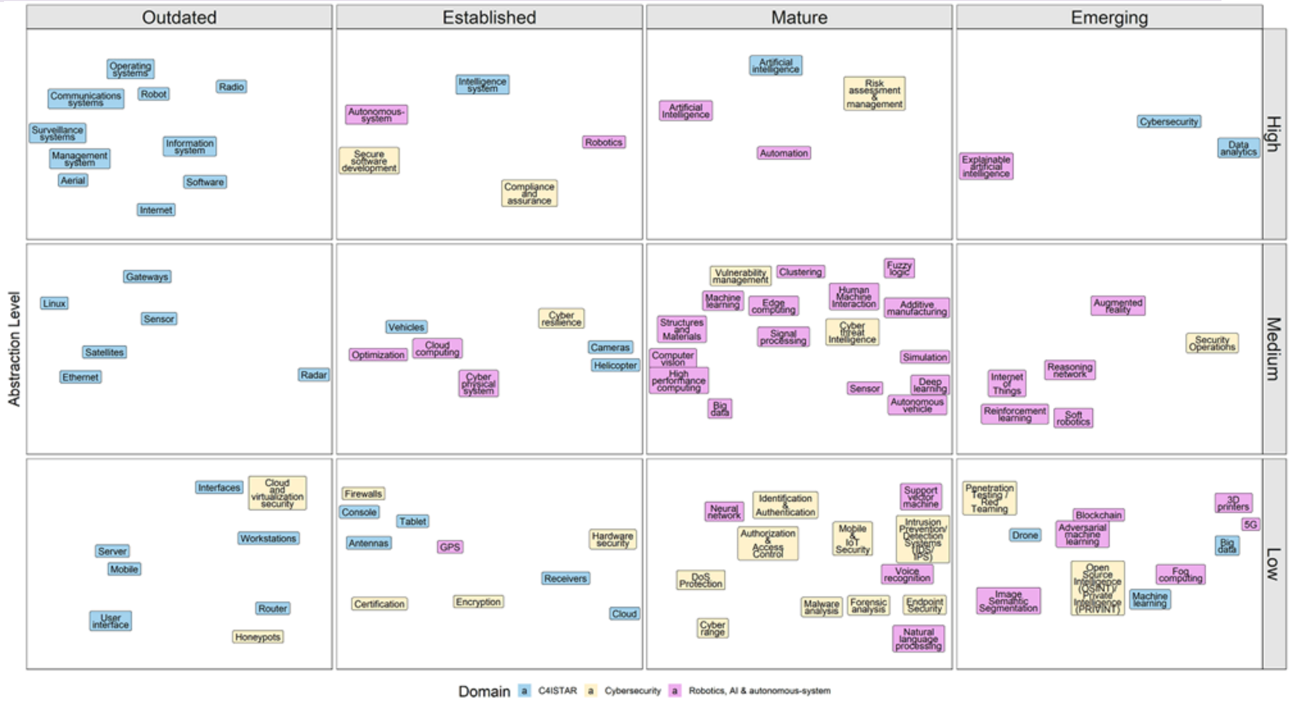

Figure 1 - Technologies map in the domains of Robotics, AI & Autonomous System, C4ISTAR and Cybersecurity.

Brainstorming sessions with industrial experts

If the first part was quantitative and data-driven, looking at the future of such a complex domain can be done only by using human expertise. Indeed, the analysis of the cutting-edge technological domains is complex, given that these are strongly entangled. In addition, the strategic issues related to the Defence knowledge and information increase the complexity of foreseeing future scenario in R&D and HR management. Therefore, qualitative methodologies may help in discovering new elements and gathering new insight [4].

We developed an updated version of C4ISTAR, a version 4.0, called C4AID. This is an acronym that stands for "Command, Control, Communication, Cybersecurity, Artificial Intelligence in Defence". This framework is for us the natural evolution of C4ISTAR, given that it includes the emerging technologies addressed in the project allows to have a systemic and holistic view of their interaction. First, for what concerns the "Cs" of the previous version (Command, Control, Communication, Computer), the Command, Control and Communication applications are still crucial for the Defence sector (and always will be). The computational part has evolved, moving to a new way of processing information, that has converged in Artificial Intelligence. This is the reason why, the "I" of the previous "Information" has been removed, leaving the space for adding "AI". At the same time, it is evident that complex and ICT related defence systems cannot now do not consider Cybersecurity. For this reason, the "Cs" are still four: we removed "Computer" and added "Cybersecurity". Finally, the "ISTAR" part of the previous framework (Intelligence, Surveillance, Target Acquisition, Reconnaissance) has been substituted by "D", standing for "Defence", that contain all the four functions.

This novel framework has the form of a matrix, and it is reported in Figure 2. It presents on the rows the technological fields under analysis in ASSETs+ (Robotics, AI, Autonomous Systems, and Cybersecurity); on the columns the main areas of the Defence sector (factory, land, air, sea, space, and the cyber-space); on the intersections the applications of a technology related to a given domain a specific Defence area.

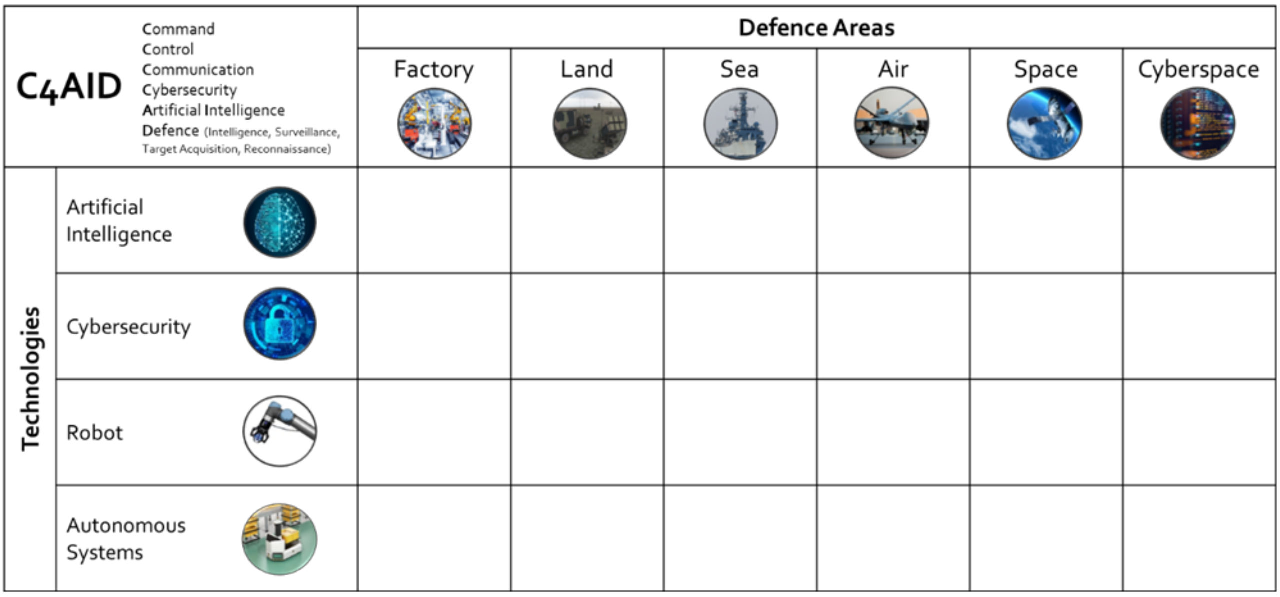

Figure 2 - Framework C4AID (Command, Control, Communication, Cybersecurity, Artificial Intelligence, Defence: Intelligence, Surveillance, Target Acquisition, Reconnaissance).

As already mentioned in the introductory part of this section, our aim is to forecast, within the scope of C4AID, technologies, skills, and education in the Defence sector. We identify the technical experts among the industrial and academic partners and group them based on similar technology-application intersection, with the purpose to set up homogeneous panels for each intersection of the C4AID matrix. In this step, we need to consider that an expert can cover more than one (adjacent of not) boxes in the matrix. After this collection is done, we can cluster together multiple adjacent boxes, creating the so-called scoping areas. Indeed, we aimed at combining different professional background to trigger ideas and discussion during the sessions, as highlighted in [5].
For each group of experts, we organise a technology-sector specific structured brainstorming session, to discuss on the future oriented time framed views of technologies, skills, and education. The structured brainstorming sessions for each scoping area are based on the following 5 rules:

- Encourage Wild Ideas: Embrace the most out-of-the-box notions. Strange ideas trigger the most interesting ideas.
- Build on the Ideas of Others: Use other ideas, and explicit the link that exists between your ideas and someone else's ideas.
- Stay Focused on the Topic: Try to keep the session on the target scoping area and step. Divergence is good, but there is the need to keep your eyes on the goal.
- One Conversation at a Time: Ability to listen to other ideas is as important as having good ideas.
- Go for Quantity: Our goal: 100 ideas per session.

Blending process

The final step of the forecasting process consists of building roadmaps, combining the results of the brainstorming session with the results of the data-driven analysis. Indeed, data-driven analysis and expert judgement are powerful methods that can lead to better results when combined rather than separated [6].
The blending process is based on a contrast and comparison all collected information, to enable the interpretation of the knowledge behind the data. The experts' ideas are compared with the technologies and applications identified in the data-driven analysis with the purpose to detect the missing elements. The elements are tagged as missing, i.e., technology or application not included dataset and to be added; or included, i.e., relevant technology or application, already included in the dataset or already exists as a

combination of technologies or in a more generic terminology. Then, the events are identified and collocated in a timeframe considering the level of maturity of the technologies. Finally, the connections are highlighted in the roadmap.

The ASSETs+ roadmap will have the form of a radar. Radar is an iconic defence-related technology, that is used as detection system, and has been chosen for several reasons. First, the product lifecycle of the radar is an example of the traditional innovation paradigm in technological R&D. Indeed, radar was elaborated for military purpose and now civil uses were widely and vary. This contrast aims to highlight the radical transformation we are experiencing nowadays. Second, radar is a detection system used to monitor a context and identify the relevant information within a given scope. It is a technological representation of the ASSETs+ goals, i.e., spot the trends in technologies and skills, translate them into concrete concepts as a basis for new education and training programs for the current and future workforce in Defence sector, leveraging on the expertise of the Consortium. Those two last elements recall the importance of human resources both in defining and applying policies, in fact the human brain is in the middle of the radar. Finally, it is the in line with the logo of the ASSETs+. The roadmap will include the most relevant job profiles, the most relevant skills for each job profiles and the most relevant technologies. The technologies will be positioned around the job profiles, considering the importance of a technology for a given job, and along the radial dimension, considering the level of maturity of a technology. In this way, the technologies, the skills, and the job profiles will be distributed in four main areas, that describes the most relevant capabilities for the Defence sector with reference to the technological domains of Robotics, Autonomous Systems, AI, Cybersecurity, and C4ISTAR. The results of these analysis will be available on the ASSETs+ website at https://assets-plus.eu/results/.

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