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ARESIBO HORIZON 2020 EUROPEAN RESEARCH PROJECT – ENRICHED SITUATION AWARENESS FOR BORDER SURVEILLANCE

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Abstract. *The paper aims to introduce the ARESIBO project to a greater but targeted audience and outline its main scope and achievements. ARESIBO stands for "Augmented Reality Enriched Situation awareness for Border security". In the recent years, border security has become one of the highest political priorities in EU and needs the support of every Member State. ARESIBO project is developed under HORIZON 2020 EC Research and Innovation program and it is the joint effort of 20 participant entities from 11 countries. Scientific excellence and technological innovation are top priorities as ARESIBO enhances the current state-of-the-art through technological breakthroughs in Mobile Augmented Reality and Wearables, Robust and Secure Telecommunications, Robots swarming technique and Planning of Context-Aware Autonomous Missions, and Artificial Intelligence (AI), in order to implement user-friendly tools for border and coast guards. The system aims to improve the cognitive capabilities and the perception of border guards through intuitive user interfaces that will help them acquire an improved situation awareness by filtering the huge amount of available information from multiple sources. Ultimately, it will help them respond faster and more effectively when a critical situation occurs.*

Keywords: *Augmented Reality; Wearables Technology; Border Surveillance; UxVs; Robotic Swarms; Mission Planning; Command & Control; Artificial Intelligence.*

Introduction

Augmented Reality was early identified as a promising technology for providing contextual information in military, security, or safety scenarios. In these scenarios, the display of relevant information supports in situ decision-making when a user is operating in the field. Typical use-cases are providing access to spatial information, e.g. maps and environmental information for decision making or tactical training. The effectiveness of providing context-specific information with AR systems has been analyzed in use cases across many domains, such as industry, health, or military. Especially in industrial scenarios, AR is of great interest in research as well as in the implementation of industrial solutions as the workers can access all the information needed for their tasks without any need to access to manuals or physical documentation. During the last decade a large number of studies demonstrated the effectiveness of AR in those settings. The most prominent scenarios can be found in logistics, assembly lines, quality control, service and maintenance. It was shown that providing context-specific and interactive visual support to workers typically increases overall performance. This can be measured by reducing completion times, reduction of error rates, and increase of quality – often all measures are improved significantly simultaneously. These findings have the potential to

scale and to be transferred to other domains as well, as the cognitive mechanisms and ergonomic benefits related to the processing of context specific information seem to be general and replicable in different scenarios.

ARESIBO is an innovative system for improved situation awareness in the border security domain. ARESIBO focuses on the execution and tactical layers by covering a wide range of multipurpose borderland operational tasks and coast guard functions including border surveillance and area examination, patrolling and tasking of unmanned platforms, situational awareness, analysis of potential threats, search and rescue activities, joint planning of field operations. The envisaged platform addresses the problem of providing enhanced and integrated situation awareness to the operational personnel acting in-situ and in the C2 control more border by developing (a) intuitive and user-friendly interfaces for border security tools, (b) cloud-based decision-support services and tools for field and C2 operators, and (c) the needed communication infrastructure to accomplish border control and security tasks.

ARESIBO considers the use of all types of unmanned systems, namely Unmanned Ground Vehicles (UGV), Unmanned Aerial Vehicles (UAVs), Unmanned Underwater Vehicles (UUVs), and Unmanned Surface Vehicles (USVs) that can meet the operational requirements of different border security missions and have the potential to lead and autonomously accomplish difficult and dangerous operations. They are force multipliers in a domain where the staffing is limited and, in addition, they can operate in locations where the safety of personal could be threatened. A large reduction of the operational costs can be expected.

Pillars of research

ARESIBO aims at improving the efficiency of the border surveillance systems by providing the operational teams and the tactical command and control level with accurate and comprehensive information. The pillars of research in ARESIBO are three-fold:

1. Set-up a complete configuration at tactical and execution level to optimize the collaboration between human and sensors (fixed and mobile assets) and enable remote briefings/debriefings through a secured cloud,
2. Improve situation awareness by enhancing the understanding of the situation through adapted processing of sensor data, correlation between heterogeneous data and information and creation of knowledge through deep learning techniques and,
3. Create a better situation understanding at C2 level that will combine reports on previous missions, real-time situation understanding and threat analysis for future actions.

The first pillar of ARESIBO and its short-term objective: a baseline is created reflecting what the present (now and short term) situation could be (regardless of financial constraints) and implement a first version of the technologies that will be used to enhance situation awareness. This baseline shall validate the feasibility to quickly integrate emerging technologies in the legacy system to produce at short term a first consistent level of capability (LOC1).

The second pillar of ARESIBO, at mid-term horizon, is to improve situation awareness by enhancing the understanding of the situation through adapted processing of sensor data, correlation between heterogeneous data and information and creation of knowledge through deep learning techniques and to implement an integrated Augmented Reality (AR) capability around the private “cloud” for both tactical C2 centers and field units. Both situation awareness processes and AR capabilities require deep/machine learning techniques to integrate the lessons learnt and improve data fusion and correlation, identification and classification and risk assessment, so an important volume of “historical” data will be needed to achieve this. These

sets of data will be provided by the end-users of the consortium and by organizations participating in the External Advisory Board.

Finally, at long-term, ARESIBO will provide orientations to enhance the EUROSUR handbook and the legislative document by providing return of experience from the tests and demos that will be performed in real and realistic environments with the support of the end-users. In particular, recommendations on the evolution of procedures will be issued to enhance the mission planning and preparation process as well as the optimization of sensors and surveillance platforms utilization and allow a close to real time collaboration between the teams in the field and the tactical C2 centers.

Aresibo objectives

The top priorities of ARESIBO will be scientific excellence and technological innovation. It will enhance the current state-of-the-art through technological breakthroughs in Mobile Augmented Reality and Wearables, Robust and Secure Telecommunications, Robots swarming and Planning of Context-Aware Autonomous Missions, and Artificial Intelligence (AI), in order to implement user-friendly tools for border and coast guards. The system will improve the cognitive capabilities and the perception of border guards through intuitive user interfaces, will help them acquire a clear and more accurate understanding of the current conditions by filtering the huge amount of available information stemming from multiple sources and, ultimately, will help them respond fast and effectively when a critical situation takes place.

The Research and Innovation Objectives (RIO) of ARESIBO that reflect the above priorities are:

1. RIO-1: Integrated situation awareness and improved perception for field and C2 operators through intuitive AR interfaces.
2. RIO-2: Better human-robot collaboration via Dynamic UxV swarm intelligence for optimized surveillance.
3. RIO-3: Secure the network connectivity between the field units and the C2 via Intelligent Hybrid Networks and Edge Computing.
4. RIO-4: Help operational units familiarize with new IT tools by means of Serious Games.
5. RIO-5: Cross-platform interoperability of data-, user- and network-interfaces and contribution to standards.
6. RIO-6: Holistic decision making based on Situational Awareness, Assessment and Forecasting tools.

Technical solution

ARESIBO technical solution is based on three technology pillars (Fig. 1). ARESIBO integrates research activities in the domain of:

1. Surveillance platforms (air, ground, surface, underwater) to optimize the collaborative capabilities of the platforms and their positioning (between themselves and with the teams),
2. Sensor processing to interpret, fuse and correlate all the data to produce information and knowledge and,
3. Augmented reality techniques to elaborate and provide to the operators with a situation awareness picture which is fit for their missions (minimum information for maximal understanding) both as team level and tactical C2 level.

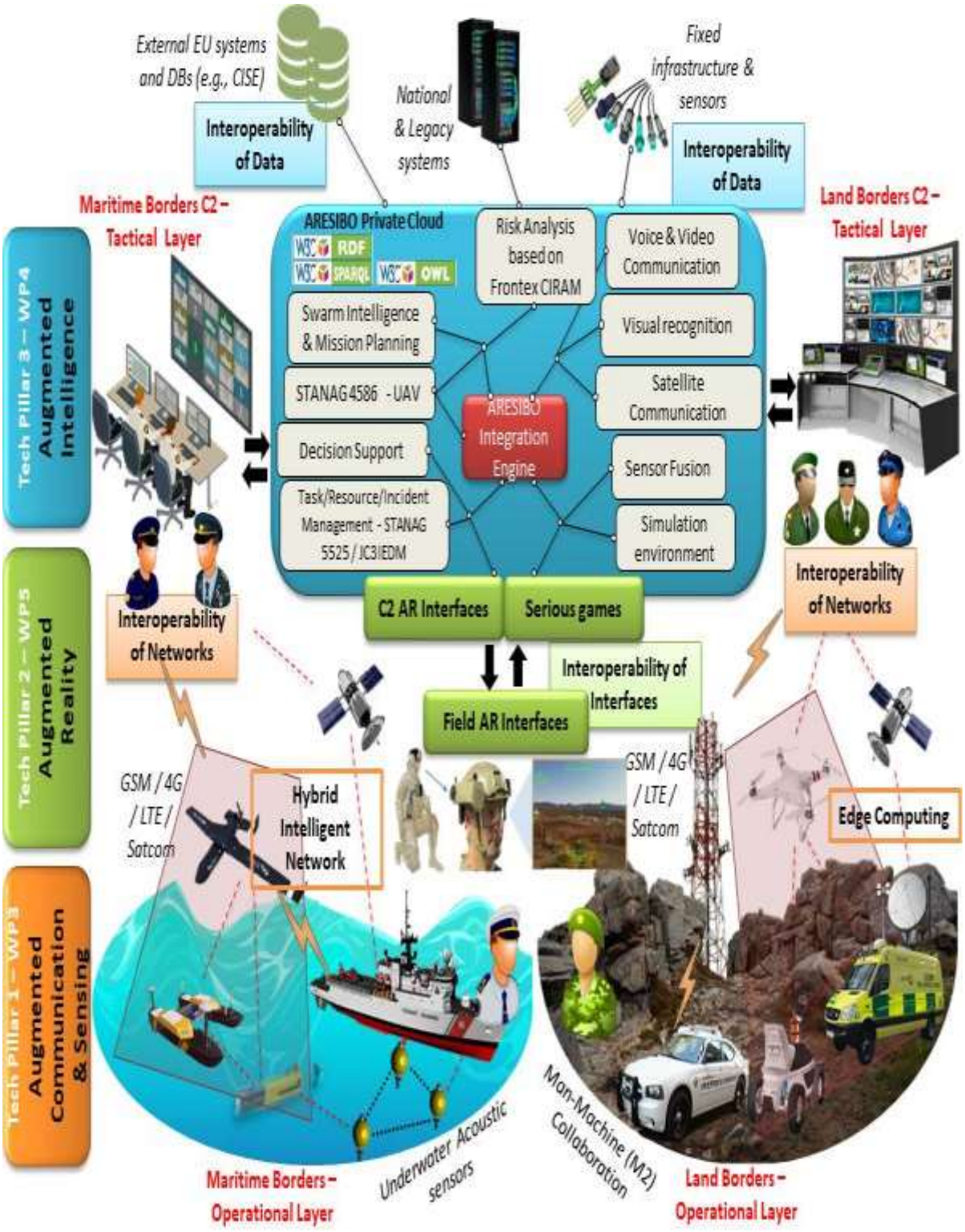

Figure 1: ARESIBO concept

In particular, ARESIBO will equip field officers, on-scene commanders and C2 operators with a holistic view of available heterogeneous data and will make the in-field activities easily accessible via non-disruptive interfaces based on Augmented Reality. ARESIBO will also provide border and coast guard personnel with a complete suite of Augmented Intelligence tools and services hosted by a private cloud-based infrastructure ready

to be used on-demand in order to fulfill their regular activities. To secure permanent connectivity between the field units and the C2, ARESIBO will deploy an Augmented Communication and Sensing infrastructure based on an Intelligent Hybrid Network equipped with secure communication protocols including Satellite Communications and 4G/LTE/5G in near future. At the same time, ARESIBO will complement the operational support with interoperable interfaces in terms of (a) standardized data and service formats for incidents/resources/tasks, (b) standardized framework for delivering AR data, and (c) interoperable network interfaces.

ARESIBO features innovative Augmented Reality (AR) interfaces provided to personnel patrolling and guarding the sensitive border areas. The project implements a distributed, small scale architecture that relies significantly on mobile assets like UAV and UGV. Such devices are capable of realizing autonomous missions with advance onboard intelligence. Specifically, the mobile assets feature cameras and other innovative sensor technologies with full geo-reference capabilities. The device collects a volume of measurements while undertaking the mission. The device operates as a typical data mule that collects measurements, stores them internally in an efficient way and delivers them to another device that it encountered or a terminal infrastructure at the end of the designated mission. The data feeds of the data mules are, eventually, collected at the computing device that the patrolling officer carries. This latter device is capable of performing all the needed processing required for the elaborate visualization of the current status on the border theater. The final device to render all dynamic information from the border area adopts the AR technology for advanced information delivery. The AR paradigm allows the visualization of incidents over a certain period of time (past) and projects such incidents (and associated data) on the user's visual field (surroundings) (Fig. 2). Thus, the user has a full situation awareness, a concept that not only covers the present status of the considered environment but also all the recent developments (historical information). Complete situation awareness provides the user with the means to project recent developments to the immediate future and, thus, improve border security and surveillance efficiency.

In essence, ARESIBO implements small, human centric systems with advanced User Interface and sensing capabilities at the service of the patrolling units and the C2 operators. The missions that are to be engaged by the mobile assets are dynamic patterns that are geo-specialized (subject to the current location of the controlling officer) and the established alarm level in the area. ARESIBO UIs will be based on monocular AR displays for the field officers and Binocular AR displays for the C2 operator.

By adopting the AR technology, ARESIBO will help the border and coast guard authorities in 3 fundamental ways:

1. By decreasing the interaction cost (i.e., time and effort) to perform a task. The field commander can remain in the current environment and have relevant data displayed right there, without doing any action.
2. By reducing the cognitive load of the user. In the absence of an AR interface, the user has to remember how to handle the specialized equipment to find information about certain actions. As a result, user's attention has to be disrupted. Such a decision increases the cognitive of the user and the effort that has to be spent in thinking how to interact with the system. ARESIBO will decrease working-memory since: (a) Its interfaces will not require users to learn commands. (b) They will allow users to move information smoothly from one context to another.
3. By integrating multiple sources of information and minimizing attention switches. With a non-AR system, if the user wanted to "save" the id of a UxV and use a different system to find its trajectory, he/she would have to switch attention from the plane to that external source of information. With ARESIBO, the two sources of information are combined because the relevant information is displayed in an overlay on top of the real object.

Figure 2: Mock-up of the field officer AR projection

Architecture

In this section, we discuss the high-level system architecture of ARESIBO. In Figure 3, we present the different components of the system, their classification considering the technology pillars, their interconnections, and their correlation with both ARESIBO actors and external systems. Following a top-down approach, the following parts of the architecture are met:

The ARESIBO Actors (yellow box). ARESIBO considers three types of actors:

- *C2 Operators* that may operate the different tools within the C2.
- *Tactical Commanders* that are the on-scene commanders when an incident takes place.
- *Field Officers* that constitute the patrol units and the coastguards that act in the field.

The three technology pillars of ARESIBO and the technical components of each pillar:

Augmented Reality pillar (cyan box). This pillar builds AR tools for all the three types of Actors considered by the system. The following components belong to the Augmented Reality pillar:

- *AR support for Field Officer*. The AR applications that will be built for the Field Officers.
- *AR Support for Tactical Commander – Binocular device*. The AR applications that will be built for the Tactical Commanders on MS HoloLens 2 device.
- *AR Support for Tactical Commander – Tablet*. The AR applications that will be built for the Tactical Commanders on Tablets.
- *AR Support for C2 Operator*. The AR applications that will be built for the C2 Operators on MS HoloLens 2 device.
- *Time-based visualization*. The time-based projection component for MS HoloLens 2 device.
- *Serious Game*. A Serious Game for user training.
- *Data communication gateway for AR*. A data connector for the AR devices in ARESIBO.

Augmented Intelligence pillar (green box). This pillar develops services and tools for the ARESIBO private cloud. The following components belong to the Augmented Intelligence pillar:

- *UxV Mission Editor*. A tool with a GUI for designing missions consisting of autonomous vehicles of all types.

- *Reasoning service*. Back-end service that combines existing data in order to deduce new and more accurate knowledge. It is based on the ARESIBO semantic models.
- *Decision Support Tool*. A tool for providing recommendations on the optimized use of resources that will facilitate decision making.
- *Simulator*. A simulation engine for user training. It will feed the ARESIBO Serious Game with data.
- *Sensor Fusion*. It provides real-time detections based on multi-level correlation of sensor data.
- *Risk Analysis*. It implements a series of predictive models to estimate risks (e.g., future position of an unidentified moving object). It uses the CIRAM terminology to label tactical and operational risks.

Augmented Communication and Sensing pillar (light orange box). This pillar designs and implements the ARESIBO network, the management of the UxVs and the sensing elements. The following components belong to the Augmented Communication and Sensing pillar:

- *Visual Recognition*. A set of visual detection algorithms based on deep learning.
- *Data communication and cyber-security*. Secure data communication solutions and protocols in ARESIBO.
- *Swarm Intelligence and Human-Robot collaboration.* Swarm intelligence schemes for optimized orchestration of missions consisting of autonomous unmanned platforms.
- *Network components and Island Gateway*. The ARESIBO network infrastructure for land and maritime environments.
- *Active sensing*. A software solution for the optimized use of sensors (e.g., control, activation, de-activation).
- *Voice and Video communication*. A solution to provide network connectivity between the on-field operators and the corresponding C2 center to support voice and video applications.
- *Resource control*. A back-end optimizer of UxV mission plans.
- *UUS/USV*. The unmanned underwater and sea-surface platforms of ARESIBO.
- *UAV*. The unmanned aerial platforms of ARESIBO.
- *UGV*. The unmanned ground platforms of ARESIBO.
- *UxV sensors*. The sensors that will be used in ARESIBO; mostly the ones attached to the unmanned platforms.
- *Underwater sensors*. Hydrophones and acoustic sensors for underwater surveillance.

ARESIBO Knowledge Base (orange box). This component contains the ARESIBO ontology network which is a set of interconnected semantic models. Within the ARESIBO Knowledge Base, the following semantic models have been designed:

- *ARESIBO Core ontology*. It is connected with other semantic models for data integration purposes.
- *CIRAM ontology.* A semantic model representing the terminology offered by CIRAM. It is connected with the ARESIBO Core ontology and it is used by the Risk Analysis module to label operational and tactical risks.

Persistency Layer (light grey box). It is the ARESIBO Storage. First it includes a Communication Middleware based on message queues (Kafka middleware). This middleware acts as an intermediate message bus that routes the messages from the sender(s) to the recipient(s) efficiently. The message follows a JSON format following and extending, whenever this is needed, the UCS3.4 data model. In addition, we use a no-SQL database to push all the messages that pass-through Kafka into a doc-oriented database.

C2 Visualisation (blue box). ARESIBO will make use of a stripped-down version of C2 environment to demonstrate interoperability between ARESIBO and external components. The basic use of C2 functionalities will be achieved through the AR C2 application.

External interoperability layer (dark grey box) – Connectors with legacy systems (red box). ARESIBO will validate its technical outcomes by checking the capability of the system to communicate with external and legacy systems. This layer provides a set of connectors for the external systems that are considered in the context of the project.

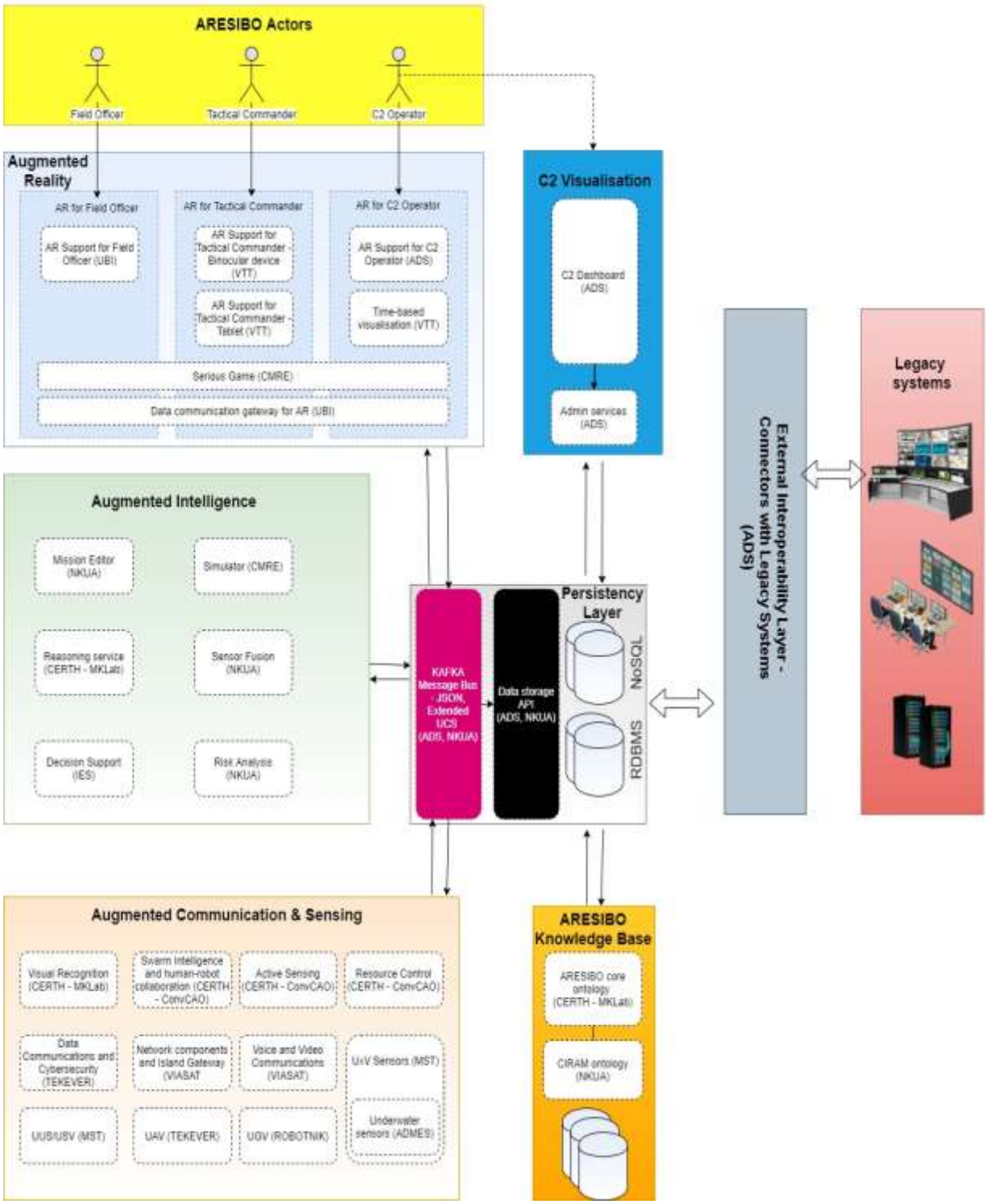

Figure 3: High-level system architecture of ARESIBO

Aresibo consortium

ARESIBO project is developed under HORIZON 2020 EU Research and Innovation program and it is the joint effort of 20 participant entities from 11 countries. This large European dimension is fundamental for demonstrating the possibility to effectively pursue future collaboration and the inclusiveness of countries in the external EU borders. The ARESIBO consortium brings together a unique combination of research, technology, demonstration, evaluation, innovation, business skills and expertise necessary to achieve its goals. The partners possess excellence in their respective field of competence, thus providing complementary know-how for the successful carryout of the project.

Participant No*	Participant organisation name	Short name	Country
1 (CO)	Airbus Defence and Space SAS	ADS	France
2	National and Kapodistrian University of Athens	UOA	Greece
3	Fraunhofer Institute for Material Flow and Logistics - Aviation Logistics	IML	Germany
4	Intelligence for Environment and Security SRL	IES	Italy
5	Ubimax GmbH	UBI	Germany
6	Centre for Research and Technology Hellas	CERTH	Greece
7	TEKEVER Aerospace Defence and Security	TEK-ASDS	Portugal
8	Robotnik Automation SLL	ROB	Spain
9	Ministry of National Defence, Greece	HMOD	Greece
10	VTT Technical Research Centre of Finland Ltd	VTT	Finland
11	Bulgarian Defence Institute "Professor Tsvetan Lazarov"	BDI	Bulgaria
12	Oceanscan – Marine Systems & Technology LDA	MST	Portugal
13	RAJAVARTIOLAITOS - The Finnish Border Guard	FBG	Finland
14	Portuguese Ministry of Defence - Naval Research Centre - Marinha	MARINHA	Portugal
15	ViaSat Antenna Systems SA	VIASAT	Switzerland
16	NATO Science and Technology Organisation - Centre for Maritime Research & Experimentation	CMRE	Belgium
17	Cross-Border Research Organisation	CBRA	Switzerland
18	Institute of International Sociology of Gorizia	ISIG	Italy
19	Romanian Protection and Guard Service	SPP	Romania
20	Advanced Mechanical Services	ADMES	Greece

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