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Abstract: This deliverable will summarize the progress made during the project's duration presenting (i) the consortium, (ii) the ROBORDER objectives, (iii) a summary of the project results, (iv) the impact achieved during the project, (v) and the final report of the data management and final release of the ROBORDER data and data access mechanism to the consortium members. The Data Management plan that will be presented represents an update from the previous Data Management plan reported in D8.4. All the activities that led to the successful completion of the project will be displayed and discussed in detail in order to depict the course of the project. To conclude, the contribution of the project to the livelihood of society will be made clear.

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Executive Summary

The present document is the final version of the self-assessment plan and final activity report. In the first part there is an overview of the consortium so that the key expertise and contribution of each partner to the completion of the project can be identified. Furthermore, the objectives of the project are presented and categorized to innovation objectives, user-oriented objectives and impact making objectives.

The innovation objectives are set according to the challenges posed by the border authorities needs and involve the utilisation of innovative border control tools, developed through the advance state of the art breakthroughs in robotics, sensing, communication and information technologies that are used in the project. The user-oriented objectives are defined in order to correlate the innovation objectives with the user operational needs. They involve the use case creation and end user requirements definition, the test case simulations and user evaluation and the human-robot concept of operations (ConOps). The impact making objectives, on the other hand, focus on the development of key strategies to exploit the main results of ROBORDER system and explore their wider use and sustainability, as well as their business feasibility. The impact objectives are divided in dissemination, standardisation, and collaboration actions with external bodies. In addition, they include a market analysis for existing solutions, an exploitation plan for the proposed tools and a sustainable product to be integrated to LEAs environments.

Having the objectives mentioned above in mind, a number of key results have been produced during the lifetime of the project. These results are analysed in detail and linked to an innovation, user-oriented or impact making objective. Also, the initial, targeted and final technology readiness level of the key results is displayed, in order to make the progress and improvement that was succeeded during the project clear.

In addition, two separate sections of the report are dedicated to the Data Management Plan and Self-assessment of the project. The Data Management Plan is an update of the previous one, presented in the D8.4 deliverable that was submitted in January 2020. Any adjustment made by then is described in detail in this deliverable. As far as the Self-assessment section is regarded, the Gantt chart, the submitted deliverables, the achieved milestones and the risk inventory that was used during the project are presented. Moreover, for every project work package a table is added containing: 1) the objectives of the WP, along with the involvement of the objective to a certain task and milestone. 2) The evaluation strategy of each objective in order to assess the quality and progress of every task and 3) lastly the success indicators. The progress of the objectives is explained using the evaluation strategy and the success indicators that are presented in the respective table.

A section of the document is dedicated to the impact that ROBORDER is expected to have. Again, the impact is divided to different fields, so that it can be more concise. In the beginning the project's contribution towards expected impact is addressed showing how ROBORDER is fulfilling the expectations posed when the project was launched. Then the impact is divided towards its footprint on technology, society and economy to provide a better understanding of the contribution of ROBORDER to the livelihood of the future.

Lastly, the final section of the report, includes the concluding remarks and highlights of the deliverable. A recap of the document is made, containing the most relevant information of the project.

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List of Acronyms

Acronym	Meaning
AI	Artificial Intelligence
AR	Augmented reality
ARTC	Autonomous Resource Task Coordination
BPO	Business Process Outsourcing
CIRAM	Common integrated Risk Analysis Model
CISE	Common Information Sharing Environment
CONOPS	Concept of Operations
DMP	Data Management Plan
DSL	Domain Specific Language
DSP	Digital Signal Processing
EC	European Commission
EU	European Union
FM	Frequency Modulation
FPS	Frames per Second
GA	Grant Agreement
GCS	Ground control station
GDPR	General Data protection regulation
GPS	Global Positioning System
GUI	Graphical User Interface
IA	Innovation Actions
ICT	Information and Communication Technology
IEC	International Electro-technical Commission
IMM	Interacting Multiple Model
IO	Innovation Objectives
IP	Intellectual Property
IPR	Intellectual Property Rights
IR	Infrared
ISF	Internal Security Fund
IT	Information Technology
LEA	Law Enforcement Agency
LTD	Limited Company
MS	Milestone
MTOW	Maximum Take-off Weight
M&S	Modelling and Simulation
NDA	Non-disclosure agreement
PR	Passive radar
PRN	Photonics-based Radar Network
PUC	Pilot Use Case
RDF	Resource Description Framework
RES_EU	Restreint EU / EU Restricted
RF	Radio Frequency
RGB	Red Green Blue
RPAS	Remotely Piloted Aircraft Systems
SAB	Security Advisory Board
SAR	Synthetic Aperture Radar
SIMROB	Simulation Environment for ROBORDER
SME	Small and Medium Enterprise
SW	Software
TRL	Technology Readiness Level
TX/RX	Transmitter/Receiver
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicle

UUV	Unmanned Underwater Vehicle
UxV	Unmanned Vehicle
VPN	Virtual Private Network
VR	Virtual Reality
WP	Work Package

Table 1 - List of acronyms.

1. Introduction

The deliverable is representing the progress made during the lifetime of the project, from M1 to M52. The document is separated into 5 sections, analysing the key elements of every section. The aim is to present how the work stated in the Grant Agreement was conducted, the achievements made, the risks avoided, and the results provided.

In the first section there is an overview of the consortium. A short description exists for every beneficiary including information about their expertise and contribution to the project. In addition, the objectives of the project are displayed, in order to give a better understating of the driving factors and aspects of ROBORDER. To close this section, every objective is correlated with a key result that is elaborated in detail, including initial and current TRL level, achievements made through the lifespan of the project and readiness for going out in the market.

The second section refers to the Data Management Plan (DMP) of ROBORDER. The DMP describes the foreseen dates when specific data will become available to the consortium and several other important date-related issues. The collection and use of any kind of data during demonstrations and pilots is also addressed in this section, along with the IP properties and possible deviations of the second review report and project planning.

The third section is dedicated to the self-assessment of the consortium. The timeplan of the project is presented including the status of planned/submitted deliverables and milestones. The risk inventory kept during the project is shown, providing likelihood, impact and possible mitigation actions to the risks. Then, every work package is divided to a number of objectives according to its stated in the Grant Agreement tasks. An evaluation strategy is referring to each objective and Work Package indicators are displayed, according to highest or lowest expectations to be fulfilled. The beneficiary responsible for an objective provides the progress made during the project, responding to the evaluation strategy and indicators.

The fourth section concerns the impact of ROBORDER. It separates the type of impact to the topic's expected impact at first giving details of the contribution of the project. Then, the footprint of ROBORDER to economy, society and technological development is addressed. Regarding the economic and technological impact, indicators and ways to measure the impact are being set. On the other hand, the societal impact due to its nature, is not evaluated using indicators but more using results that could benefit the society and livelihood in general.

In the end, the concluding section of the report takes place. The highlights of the project are mentioned once more and a wrap up of the activities discussed in previous sections is available.

1.1 Consortium

The ROBORDER consortium consists of four private companies (EVERIS, ELETTRONICA, MST, EVADS), three SMEs (ROBOTNIK, COPTING, CLS), five border authorities (GNR: Portuguese National Guard, ORFK: Hungarian National Police, RBP: Romanian Border Police, HMOD: Hellenic Ministry of Defence and BDI: Defence Institute "Professor Tsvetan Lazarov"14) , two LEAs (PSNI, MJ), two security organisations closely working with border authorities (EASS, SPP), one port authority (AdSP MTS), four research centres (CERTH, FHR, VTT, CMRE, CSEM) and three academic institutions (CENTRIC, UOA, CNIT). The consortium was generated in this way in order to provide the competence needed for achieving the objectives of the project. The partners are committed to their tasks and their competence is complementary to cover all aspects addressed in the project. As a result, a capable team is formed with significant working relations within the consortium where teams have collaborated on past projects.

1.1.1 Centre for Research and Technology – Hellas (CERTH)

The Centre for Research and Technology-Hellas (CERTH) is a research centre founded in 2000, participating in the consortium through the Information Technologies Institute (ITI). ITI's related areas of research are image and Signal Processing, Computer & Cognitive Vision, Pattern Recognition and Machine Learning, Human Computer Interaction, Virtual and Augmented Reality, Artificial Intelligence, Multimedia, Database and Information Systems and social media analysis as well as Security and Surveillance applications. CERTH acted as a Work Package leader in WP4 dealing with the development and of command-and-control unit functionalities for the situation assessment and operational management and as a task leader in the development of an oil-spill detector using SAR images (T3.1), in the multimodal fusion strategy (T3.3) and in the visual recognition tasks (T3.2). In addition, CERTH had leading role in T4.3, T4.4 and T4.6 where the autonomous resource controller, the CISE-based common representation and the decision support were delivered respectively. In addition, CERTH was responsible for the website and web presence of the project (T7.2). Lastly, CERTH was the delegate of the consortium to the European Commission (EC) as the project's coordinator as well as the Scientific and Technical manager of the project to monitor the technical progress at all levels.

1.1.2 TEKEVER Autonomous Systems (TEK-AS) (Terminated on 15/12/2018)

TEKEVER is a product-driven small and medium size enterprise (SME) that develops creative disruptive technologies for the information technologies, aerospace and security markets. The partner's involvement in the project was terminated by the Commission since 15/12/2018. After that period, the beneficiary has no further involvement in the project.

1.1.3 Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR)

The Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) is a research organisation founded in 1949 that undertakes applied research that drives economic development and serves the wider benefit of society. The Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) develops concepts, methods and systems for electromagnetic sensors, particularly in the field of radar and radiometry, together with innovative signal processing methods and innovative technology from the microwave to the lower terahertz region. The institutes´ competence covers almost every aspect of modern radar technology and practically all radiometry techniques. FHR led T2.2, coping with the design and deployment of an optimized passive radar on board UAVs and USVs, contributed to WP5 working on the integration of the passive radar with other ROBORDER sensors and was involved in the prototype evaluation in WP6 and the dissemination activities in WP7.

1.1.4 Estonian Academy of Security Sciences (EASS)

Estonian Academy of Security Sciences (EASS) is a research and education centre closely working with border authorities established in 1992. The objective of the EASS is, through internal security related academic education, research and development activities, and also through the training of honest and competent public servants, to create a secure state and conditions for stable development across the state of Estonia and therewith contribute to the security of the entire European Union (EU). EASS was involved in the WP1, working in the development of end user requirements (T1.1) regarding border surveillance operational aspects and the design of the pilot use case (T1.4) scenarios. In addition to this, was involved in designing and evaluating specific pilot use cases in the context of the ROBORDER's demonstrations (T6.4 and T6.5) and took part in the dissemination activities (WP7).

1.1.5 VTT Technical Research Centre of Finland Ltd (VTT)

VTT Technical Research Centre of Finland Ltd (VTT) is a research organisation providing expert services for its domestic and international customers and partners serving both private and public sectors. VTT develops new smart technologies, profitable solutions and innovative services. VTT cooperates with customers to produce technology for business and build success and well-being for the benefit of the society. VTT was a task leader in the design of the concept of operations (T1.5) and the design of fluent human-robots interface (T4.1). VTT also contributed in the system integration activities of WP5 (T5.2), the prototype demonstration and evaluation of additional features in WP6 (T6.4 and T6.5) and in the dissemination activities of WP7.

1.1.6 Everis Spain SLU Succursale Belgique (EVERIS)

EVERIS is a private multinational consulting company that offers its clients comprehensive business solutions covering all aspects of the value chain, from business strategy to systems implementation. The business areas covered by EVERIS are business consulting, solutions, operations, Business Process Outsourcing (BPO) and initiatives, operating in the following sectors: telecommunications, financial, industrial, utilities, energy, public administrations and health. In the ROBORDER project, EVERIS undertook the leadership of WP7 dissemination and exploitation activities, leading tasks T7.4 (Market analysis), T7.5 (Business model) and T7.6 (Exploitation and long-term sustainability plan). In addition, EVERIS led the software integration (T5.2) and performed the ROBORDER system's integration and maintenance in the testing environment.

1.1.7 Police Service of Northern Ireland (PSNI)

The Police Service of Northern Ireland (PSNI) is the Law Enforcement Agency (LEA) in Northern Ireland with responsibility for policing and security, established in 2001. Specialist areas of expertise can be summarised as follows: End user requirements, Stakeholder consultation and engagement, ethical, legal and societal requirements, end-users validation, dissemination and exploitation activities, project management and coordination. In ROBORDER PSNI was involved in the development of user requirements (T1.1) as well as in the design of the pilot use cases (T1.4). PSNI provided end user feedback in the development of technical solutions through various work packages like T3.1, T3.2, T4.1, T4.4, and T4.6. Lastly, was involved in the prototype evaluation within WP6.

1.1.8 Guarda Nacional Republicana -Ministério da Administração Interna (GNR)

The Portuguese National Guard (GNR) is a border authority whose origins date back to 1801. GNR's General Mission expands in the following areas: Policing which comprehends the Criminal Police and the Administrative Police mission, Support and Rescue, Honorific and State representation and Military. At the level of national territory, the GNR is liable for the surveillance of the maritime border. In ROBORDER, GNR led the T6.4, where the beneficiary was responsible for organising and performing the Portuguese demonstration where the 2ndprototype was evaluated for marine border threats and pollution incidents. Also, GNR provided knowledge and requirements in the context of technical tasks such as T5.5, T1.1, T1.4 and contributed to the WP7 dissemination and exploitation activities.

1.1.9 NATO Science & Technology Organization (STO) Centre for Maritime Research & Experimentation (CMRE)

The Centre for Maritime Research and Experimentation (CMRE) is a scientific research and experimentation facility located in La Spezia, Italy. CMRE was established on 1 July 2012 as part of the NATO Science & Technology Organization. CMRE is a leading research centre in ocean and environmental sciences, acoustics communications, modelling, simulation and other disciplines. CMRE is leading different researches in the area of autonomous systems for the Science and Technology Organization within NATO. In particular there is a series of specific Programmes of Work (PARC, MUSE) focused on the study of novel solutions for the study of innovative applications of autonomous systems (surface and underwater) and for improving their performance and persistence at sea. In ROBORDER, CMRE coordinated WP6, dealing with the verification, validation and testing activities of the ROBORDER platform. In addition, CMRE contributed with its know how in Modelling and Simulation (M&S) developing a M&S test bed capability of HLA interoperable simulators which has been used to support CD&E efforts of partners. CMRE also led the standardization and collaboration activities of the project (T7.3) and significantly contributed in the user requirements (WP1) and the dissemination activities (WP7).

1.1.10 Hungarian National Police (ORFK)

The Hungarian National Police is, the only general police and law enforcement agency in Hungary with more than 42.000 sworn members. Specialist areas of expertise of the ORFK can be summarized as follows: Border policing tasks (as the former Border Guard was integrated into the National Police in 2008), law-enforcement, operating the situational network centre covering all Hungary, own risk analysis department, more than 120 years of experience in policing, strong international cooperation capabilities, sound experience in training staff in the use of e-learning network, use of different media to inform public. In ROBORDER, ORFK ensured proper ethical and legal framework (T1.3) and led the development of a complex e-learning environment with 6 modules for ROBORDER operators and provided online training for operators participating in the trials (T6.2). Lastly, ORFK took part in the user requirements (WP1) and dissemination activities (WP7).

1.1.11 Robotnik Automation SLL (ROBOTNIK)

Robotnik is a small and medium size enterprise (SME) funded in 2002 and is currently a leading company in the European service robotics market. Robotnik specialises in: Robotics product manufacturing and distribution, Robotics R&D and Engineering projects, Service Robotics Application, UGV Engineering. In ROBORDER, Robotnik led the re-configuration of agents to adapt to extreme and diverse weather and sea conditions (T2.5) as well as contributed in optimizing the available sensors for a variety of conditions (T2.4). In addition, was involved in the evaluation of Resource controller (T4.3), contributed in the hardware and system integration (T5.3, T5.4) and participated in both the demonstrations and the evaluation of the prototypes (T6.4, T6.5). Lastly, they were involved in the dissemination activities (WP7).

1.1.12 Romanian Protection and Guard Service (SPP)

The Romanian Protection and Guard Service (SPP) is a security organisation closely working with border authorities in the field of national security, specialized in providing protection for the Romanian dignitaries, the foreign dignitaries during their stay in Romania and their families, within its legal competence. It also provides guard for the headquarters and residences of the above-mentioned dignitaries in accordance with the decisions of the Supreme Council of National Defence. SPP in ROBORDER is an active and user partner that contributed in the end-user requirements (T1.1) and the design of the pilot use case (T1.4), as well as test scenarios and field validation (WP6). In particular, SPP along with RBP designed and evaluated the pilot scenario regarding the “Detection of terrorist attack coming through cross border”. Lastly, SPP was involved in the dissemination activities (WP7) in the context of the demonstrations.

1.1.13 Elettronica GmbH (ELETTRONICA GMBH)

Elettronica is a private company founded in 1978 and since then has been growing as an engineering system house with development, production and system integration capabilities. ELETTRONICA GMBH has designed, prototyped, developed, integrated, and validated (i) sensor systems and payloads for surveillance, interception and signal analysis for Customers in Germany, the Netherlands and Middle East, and (ii) special platforms for surveillance operation for police forces in and outside Europe. In parallel, ELETTRONICA GMBH has developed unique systems for scenario modelling and simulation, which support the validation of netted sensor devices. In the project Elettronica led WP2 activities and contributed to T3.5, where the objection was to develop and deliver a detection system for malicious and illegal emissions based on the passive microwave payload (RF sensor). Lastly, participated in the system integration activities of WP5 in order for the RF sensor to be fully operable (T5.3), the prototype demonstration and evaluation in WP6 and the exploitation activities of WP7.

1.1.14 Hellenic Ministry of Defence (HMOD)

The Hellenic Ministry of Defence (HMOD) is a public border authority that applies the Government’s National Defence Policy. HMOD implements interventions focusing on the facilitation of the interaction with citizens like the digitalization of recruitment archives and services, the generation of digital charts and weather reports, and also incorporates departments and units that address social issues like public protection, crisis managements, search and rescue operations, humanitarian aid and social and environmental research. HMOD in ROBORDER led WP1 and provided knowledge towards technical requirements in WP3 and Wp4 tasks. They were responsible for the dissemination activities (T7.1) and for organising the final demonstration of ROBORDER at the end of the project in the context of T6.4 and in collaboration with CERTH. In addition, HMOD contributed extensively to end user validation and testing (WP6) running a pilot scenario related to “Unauthorized see border crossing”.

1.1.15 Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research (CENTRIC)

Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research (CENTRIC) is a research organization aiming to develop an intersection between four key stakeholders in the security domain: Citizens, Law Enforcement Agencies (LEA’s), Industry and Academia. The mission of CENTRIC is to provide a platform for researchers, practitioners, policy makers, and the public, to focus on applied research in the Security domain. CENTRIC has close links with local, national and international LEA's and security specialist groups and is currently collaborating with a number of law enforcement agencies and leading technology providers. In ROBORDER CENTRIC primarily supported tasks related to command and control functionalities (WP4) and contributed to threat detection through activity recognition (T3.2) and data fusion activities (T3.3). Lastly, Centric took part in the system integration activities (WP5), the evaluation plan (T6.1) and the dissemination activities of WP7.

1.1.16 Port Network Authority of the North Tyrrhenian Sea (AdSP MTS)

Port Network Authority of the North Tyrrhenian Sea(AdSP MTS) is a non-economic Public Body in charge of guiding, programming, coordinating and controlling port operations and other commercial and industrial activities carried out in the Livorno port. Their skills/experience/technologies include stakeholder consultation for defining the prot needs and requirements, capability of integration of existing and new heterogeneous infrastructures, expertise in digitalisation and convergence of harbour information in a virtual platform, system test capability, dissemination and exploitation of new adaptable and viable solutions. In ROBRODER, AdSP MTS hosted a pilot installation related to “Early and effective identification of passive boats moving ashore”. Also, provided insight regarding the port operational issues for the end-users requirements (T1.1) and the pilot use cases (T1.4) and eased the dissemination and exploitation activities in the most relevant technical committees at the European scope (WP7)

1.1.17 OceanScan -Marine Systems & Technology, Lda (MST)

Oceanscan -Marine Systems & Technology, Lda, (MST) is a Portuguese company devoted to the development, manufacturing and commercialization of small-sized, one-man portable Autonomous Underwater Vehicles (AUVs). The company’s flagship product –the LAUV (Light Autonomous Underwater Vehicle) –is an underwater robot designed to answer environmental, inspection and security applications. MST brought to the project its unmanned vehicle equipment for surface and underwater surveillance. In the framework of adapting the equipment to extreme condition they were involved in T2.4 and T2.5. They took part in the hardware and system integration tasks (T5.3, T5.4) and in the prototype demonstration and evaluation of marine related demonstrations (T6.4). Lastly, MST contributed in the dissemination activities (WP7).

1.1.18 Defence Institute “Professor Tsvetan Lazarov” (BDI)

Bulgarian Defence Institute "Professor Tsvetan Lazarov" is the main scientific-research, testing-design and expert-technical structure in the Ministry of Defence of the Republic of Bulgaria. The BDI has expertise in a wide range of activities including: HMEs and IED, Armaments and ammunition, CBRNE, Cyber defence, UAVs, UVSs and USVs, Telecommunications, IT systems development. Within the project, BDI ensured appropriate security framework for project implementation (T1.2). BDI also coordinated and led the T6.5 regarding the prototype demonstration and evaluation for land border threats and providing a test site at Bulgaria for running a pilot scenario about the “Unauthorized land border crossing”. Lastly, BDI contributed to the project’s dissemination activities.

1.1.19 COPTING GmbH (COPTING)

Copting is an SME working as a full service provider for UAV operations (consulting, operations, construction, training and research). Copting is engaged in the professional and industrial UAV business. Covering the industry and public services needs with technical and operational consulting to the use of UAVs, the company also operates UAVs for clients, designs and builds UAVs up to 25 Kg MTOW and is providing flight training and support. In ROBORDER, they were involved with their unmanned vehicles in aerial surveillance and worked in the context of T2.5, T2.4. They contributed in the hardware and system integration (T5.3, T5.4) and in the evaluation and demonstration of both the land and marine (T6.5, T6.4) border-related operational scenarios as well as in exploitation activities (WP7).

1.1.20 National and Kapodistrian University of Athens (UOA)

The University of Athens (UoA) participates in the project through the Pervasive Computing Research Group (P-COMP) which is part of the Communication Networks Laboratory (CNL) that was founded in 1994. In recent years, UoA has been heavily involved in several European ICT and National projects with focus on the design and implementation of domain-specific languages, integrated development tools, context-aware platforms for the pervasive and mobile computing domain and applications of artificial intelligence and machine learning algorithm. In the project their main contribution was in the leadership of T4.2 and T4.5 where a DSL mission specification and the risk models were developed, respectively. UoA was also involved in WP3 (T3.3, T3.4) tasks as well as WP4 tasks (T4.3, T4.6). Lastly, UoA took part in integration activities (WP5), in the evaluation and demonstration of the prototypes (T6.4, T6.5) and the dissemination activities WP7.

1.1.21 Swiss Center for Electronics and Microtechnology SA (CSEM)

CSEM, Centre Suisse d'Electronique et de Microtechnique SA (Swiss Center for Electronics and Microtechnology), founded in 1984, is a private research and development centre, which has specialized in microtechnology, nanotechnology, microelectronics, systems engineering and communications technologies. It offers its customers and industry partners tailor made innovative solutions based on its technological expertise from applied research. Within ROBORDER, CSEM designed, developed and characterized in collaboration with CNIT a low-noise optical clock for photonics-based radar network (T2.6). They were also involved in integration tasks (T5.3, T5.4), in evaluation and demonstration of the prototypes (T6.4, T6.5) and the dissemination activities of WP7.

1.1.22 National Interuniversity Consortium for Telecommunications (CNIT)

CNIT is a non-profit, university-generated consortium of 37 Italian universities. CNIT brings together member and partner staff and facilities to the aim of coordinating innovation in the field of telecommunications. CNIT aims at promoting and coordinating research in telecommunications, fostering partnerships among industries, operators, public and private research centres, providing training programs, stimulating initiatives of scientific research and divulgation. The role of CNIT in ROBORDER was to design and implement the photonics-based radar network and assure its interoperability with the existing infrastructure (T2.6), and to contribute in the identification and tracking of objects of interests by processing the corresponding photonics radar data (T3.2). They also participated in the software and hardware and system integration activities (T5.2, T5.3, T5.4), the evaluation and demonstration of the prototypes in marine related operational scenarios (T6.4) and the dissemination activities in WP7.

1.1.23 Polícia Judiciária –Ministério da Justiça (MJ)

Polícia Judiciária (PJ), the Portuguese Criminal Police, is a higher criminal police body under the Ministry of Justice, supervised by the Public Prosecution Authority. Its assignments are, in general, criminal prevention and investigation, as well as supporting prosecuting and judicial authorities. As a criminal investigation police force, PJ is competent for the prevention and investigation of serious and organized crime. In the project MJ worked with GNR in running and evaluating a pilot scenario related to “Detection of marine pollution incidents” and marine related illegal activities. Additively, they were involved in the specification of user requirements (T1.1) and pilot use cases (T1.4) and the dissemination activities (WP7).

1.1.24 CyberLens LTD (CLS)

CyberLens LTD(CLS) is a start-up company based in London, United Kingdom specialising in cyber security and privacy engineering. The company was established in May 2015 by former researchers pursuing the application of their research expertise and innovations in the industrial arena. The company’s portfolio includes software development, IT research, and business consultancy. In ROBORDER, CLS led the detection and classification task for recognizing cyber and cyber-physical attacks (T3.4) and contribute significantly to the identification and tracking of illegal communications (T3.5). CLS was also involved in the software (T5.2) and system (T5.4) integration activities as well as the dissemination activities of WP7.

1.1.25 Romanian Border Police (RBP)

Romanian Border Police (RBP) is a single authority responsible for border control at all Romanian borders with centralized organization at national, regional and local level. RBP is a border authority that co-ordinates the activity of its subordinated structures and carries out activities of investigation and inquiry of the serious crimes in the field of border related offences such as organized crime, illegal migration and cross-border crime. Within the scope of the project, RBP was an active contributor for the identification of end-user requirements (WP1), as well as test scenarios and field validation (WP6). In particular, RBP along with SPP designed and evaluated a pilot scenario regarding the “Detection of terrorist attack coming through cross border”. In addition, they contributed to ROBORDER’s dissemination activities (WP7) organizing a user day in collaboration with SPP.

1.1.26 Everis Aerospacial y Defensa (EVADS)

Everis ADS is a multinational group born in Spain with a commercial network around the world that provides global solutions for critical systems in the field of Aeronautics, Space, Defence, Security and Emergency, based on engineering developments and innovative technologies developed both in-house and by third parties. EVERIS ADS does provide the most leading technology developed by ten Spanish companies which make up the group, taking advantage of the flexibility and speed in R&D and innovation processes. In ROBORDER EVADS lead WP5 dealing with the entire process of integration. They participated in WP2 tasks to adapt their assets to be integrated with the ROBORDER system. They also supervised T3.5 in order to complete successfully the module for identifying unauthorized RF communications. They developed the Command & Control Dashboard in the scope of T4.7 and, acting as a substitution of TEK in integration activities, they performed as the main system integrators, leading the WP5 with tasks T5.3, T5.4 and T5.5 as well. Lastly, EVADS was involved in the prototype evaluation in WP6, participating in the three demonstrations of the project and collaborated with dissemination activities in WP7.

For this project EVERIS ADS will bring the expertise in Unmanned Aerial Vehicles of one of these companies in the group, SCR. SCR -Sistemas de Control Remoto, S.L. was founded in 1994 and is Spanish leader in design, manufacture and service of target drones &

UAVs with over 650 aircrafts built and more than 2.000 flights performed. It stands out as the only Spanish company mass-producing target drones & UAVs, boasting a broad range of product and services.

1.2 Objectives

The threat of political violence in Europe and the unpredictable and often sudden nature of global change have increased the significance of border security among EU member states' security strategies. The ROBORDER platform aims at developing and demonstrating a fully-functional autonomous border surveillance system with unmanned mobile robots including aerial, water surface, underwater and ground vehicles (UAV1, USV, UUV and UGV), capable of functioning both as standalone and in swarms, which incorporate multimodal sensors as part of an interoperable network. In this section, all the objectives set by the consortium in the beginning of the project, will be categorized and analysed in order to assess their efficiency and implementation.

1.2.1 Innovation objectives

Innovation objectives address specific challenges defined by the border authorities current and foreseen needs, in order to utilise the innovative border control tools aimed to be developed through the advance state of the art breakthroughs in robotics, sensing, communication and information technologies that are used in the project. These innovation objectives (IO) have been categorized to innovation activities (IA) in order to make their differences and impact clear.

1.2.1.1 Adaptable sensing, robotics and communication technologies for different operational and environmental need.

The protection of long stretches of borders with heterogeneous terrain is extremely challenging, particularly when it includes areas unapproachable by humans or is marked by adverse weather conditions. Human patrols are subjected to strenuous and often dangerous work. This has led to the recent rise in the use of UxVs as they present distinct functional advantages over manual patrolling (e.g., manned vehicles). This is also documented by the fact that European Commission initiated several projects under the auspices of the European Border Surveillance System (EUROSUR) suggesting the establishment of smart border control systems that will be also capable of including the use of UAVs. Under this objective, ROBORDER did explore how existing border control infrastructure can exploit the current technological advancements on sensing, robotics and communication to respond to varying operational, environmental and geographical conditions. In particular, IO1 did introduce a layer of base technologies for sensor optimization, robotic platform re-configuration (including changing and carrying functionalities), passive and photonics-based radar extensibility, static and mobile sensor interoperability and hierarchical, reliable and secure communication. In the context of IO1 dealt with the following research and innovation activities.

IA1.1 Hierarchical, cloudlet-based communication network architecture to support context-aware reliable and secure communications in large UxV fleets. Following updated versions of D1.2 “Final concept of operation, use cases and requirements” [RESTREINT UE/EU RESTRICTED], the consortium decided to reject cloud-based communications as this feature will insert multiple security vulnerabilities. Instead, a locally deployed system was adopted by incorporating the appropriate network infrastructure reported in D5.5 “Final Integrated ROBORDER System” [RESTREINT UE/EU RESTRICTED].

IA1.2 Optimized passive radar on board UAVs and USV.

The main objective of this activity was to extend the radar coverage of a photonic radar network (PRN) which was developed by CNIT. In order to achieve this goal, the FHR has led the development and implementation of Passive Radar (PR) to be mounted on both UAV and USV platforms, thus enabling such platforms to patrol the coast and/or the border of interest at wider coverage areas. The PR system was developed and tested on various trials. During the latest trial, the PR system operated in a real scenario using two transmitters, developed at FHR as the replica of the PRN for target over ground. The data from the trials was successfully tested and integrated with the overall ROBORDER system via the MoniCA platform. The PR system was again validated in real time during the operational test in July 2021 in order to deliver a TRL 7 service.

IA1.3 Passive radio-frequency signal sensor on board unmanned platform.

A portable RF sensor has been successfully developed, verified and validated in different trials and demos. The RF sensor has proven his ability to early detect and track unauthorized communication (e.g. UAVs and remote controls) and Jamming activities in ROBORDER operative spectrum.

IA1.4 Optimisation of sensors for a variety of operational conditions.

A simulation environment (SIMROB) has been developed based on the adaptation of the Elettronica advanced simulation environment EWTISS. It allowed the analysis of user requirements under consideration of operational aspects. SIMROB enabled the user to test several use cases previously defined and assessed the usage of the different assets planed within the ROBORDER framework (e.g. Path Optimization).

IA1.5 Re-configuration of agents, including carriers and charging solutions, to adapt to extreme and adverse weather and sea conditions.

The main objective of this activity was to design UxV, mainly UGV (Ground) and small UAV (Aerials), that are adapted to operate in different climate conditions, specifically high and low temperatures, rain, environmental humidity, and strong winds. To this end, existing UxV have been adapted to incorporate ruggedized sensors and actuators. A solution to deploy and recharge a small UAV from a UGV has also been developed. The results of this activity were tested during second demonstration, however, not all functionalities were demonstrated during the demonstration due to a malfunction of one of the vehicles.

IA1.6 Multi-static photonics-based radar network interoperable with existing infrastructure.

In this innovation activity, a novel radar network has been developed based on photonics, at the Port of Livorno (Italy). The photonic approach has allowed exploiting the existing fiber infrastructure of the port, to implement a one-of-a-kind distributed radar network where a single central unit provides the RF signals to multiple remote radar heads, and receives back the RF echoes from the observed scenario, via a special RF-over-fiber communication system. Moreover, the system manages radar signals in two separates frequency bands (namely, in S band and X band). Thanks to the centralized approach, the photonics-based radar network could process together all the signals from the different radar heads and in the different frequency bands, collecting a very rich information from the scenario under observation (thanks to the spatial and frequency diversity), with the aim of improving the radar control of maritime traffic. The results demonstrate an excellent detection capability and sensitivity. Moreover, the system opened up the possibility to also exploit the intrinsic coherence of the detected RF signals, made available by the peculiar photonics-based system, to largely improve the detection resolution from the analysis of the phase variations of the involved signals. The photonics-based radar network has been made communicating with the data infrastructure governing the port of Livorno, and from there with the ROBORDER platform.

1.2.1.2 Detection and identification of border-related threats

The large amount of data that are made available by the numerous sensors considered in ROBORDER, must be processed effectively and quickly, detecting, classifying and identifying border-related threats and critical situations in order to inform border control investigations. To accomplish this objective, the following innovation activities have been implemented.

IA2.1 Detection techniques for pollution incidents.
The main objective of the activity was to design, develop and validate the oil spill detection model under a real operational scenario. To this end, the corresponding model processes both SAR (Synthetic-Aperture-Radar) images and visual (RGB) streams to identify oil slicks over sea surface depending on the available sensor configuration. The developed service has been designed and validated under laboratory conditions using proper datasets to result a specific TRL value. The delivered model has been incorporated as a service and validated under real scenario during the 1st demonstration event in order to deliver a TRL7 service following CERTH contractual obligations.
IA2.2 Identification and tracking of illegal activities.
The main objective of the module was to identify and track illegal activities. Due to the diversity and the complexity of the under identification illegal events, the consortium decided to discriminate the latter based on the involved sensors and according to the available technologies. Thus, the task has been separated into three submodules to cover the following

- Photonics-based activity recognition
- Visual object detection and tracking
- Illegal activities recognition

Considering the data acquired by the photonics-based radar network, a specific software module has been developed implementing the detection and tracking of boats and vessels. The detection module takes into account two kinds of operations: the non-coherent multi-input/multi-output (MIMO), which exploits the geometric and frequency diversity to reach an advanced resolution on a large observation area, and the coherent MIMO, which pushes the performance to a hyper-fine resolution when focusing on specific observed targets. These modules have been tested on both simulated data, and exploited on real data during a specific operational test. Once the targets are detected and tracked, the information is passed to the Port monitoring application that shares the traces data with the ROBORDER platform. Concerning the visual object detection and tracking module, the main objective of the service was to identify instances of interest that might appear in the under-surveillance territory and localize them on the projection plane. To this end, a robust and versatile state-of-the-art object detector has been adopted to be part of the final prototype. The model was trained on a dataset that would meet the project's requirements concerning the objects under investigation. To this aspect, 13 classes of objects have been selected as the main object list that follow the end-user requirements. Apart from the object detector, a tracker has been incorporated in order to facilitate the tracking task of t5he detected objects. All relevant services have been fully incorporated into the project's main system as part of the service list and have also been validated under real operational scenario during the 2nd and the 3rd demonstration in order to deliver a fully functional TRL7 modules.
IA2.3 Low-level fusion to increase the recognition capabilities.
The main objective of the activity was to develop low-level fusion techniques from heterogeneous platforms to combine sensory data towards improving the location accuracy. To this end, two different approaches have been developed depending on the available hardware configurations, multi-modal image fusion and low level sensor

fusion (JDL-0). The first approach focused on fusing two distinct image representations of the same scene (combining visual and thermal spectrum) into one single enhanced representation that might increase the detection accuracy and enable the operations under diverse weather conditions. The second approach aimed at combining various sensory streams (e.g. GPS, IMU) that will improve the current position of the asset and thus, the estimated position of a detected object. Due to configuration restrictions, the latter approach has been validated as a delivered service by comparing the output of the module with the path obtained by the mission planning module, so that the service could be delivered as TRL5.

IA2.4 Detection framework for recognising cyber and cyber-physical attacks.
The main objective of this activity was to develop a framework to increase the situational awareness of ROBORDER's autonomous agents (UxVs) by detecting cyber and cyber-physical attacks against them. To this end, a statistical-based reasoning engine and a deep learning-based reasoning engine were designed and implemented to allow the autonomous agents to self-detect when an anomalous condition occurs by monitoring various data sources (e.g., UxV telemetry data). The developed module (entitled IDCM) has been designed and validated under laboratory conditions using proper datasets from the autonomous agents. The module has been incorporated within a service and validated under the operational test PUC2.1 "Detecting Jamming Attacks" that was conducted during the 2nd demonstration in order to deliver a TRL6 service.

IA2.5 Identification and tracking of unauthorized communication.
The main objective of this innovation activity is to develop and evaluate a sub-system capable of detecting unauthorized communication. With this aim, the measurements/raw data of the RF Sensor (built by ELT based on a SDR receiver and a circular array) were taken as an input to be processed with different algorithms that can detect and classify this kind of communications. The results have been compared to the ELT processed data using own detection and identification algorithms. This system was included in the Final Integrated ROBORDER System and evaluated during the second demonstration in order to achieve a TRL7. In the trials Jamming activities could be successfully sensed.

1.2.1.3 Tele-operation of autonomous agents through a 3D user interface and decision support

The core functionalities that refer to this Innovation Objective focuses on delivering services to improve the operational capacity of an operator. More specific, the goal was to develop and incorporate models in the final prototype that will facilitate the entire processing of operating the system at all levels, from commanding the available assets to properly inform the operator with comprehensive alerts. To this end, part of this Innovation Objective targets the delivery of easy-to-use User Interfaces which will facilitate the ROBORDER use from end-user perspective. In addition, the second target relies on presenting the detection outcomes in a proper format using the developed alert mechanism so as to support them on the decision-making process.

IA3.1 Novel human-robot interface exploiting immersive 3D virtual reality environment and/or augmented reality interface.
The main objective of this service was to develop a novel interface enabling the operator to monitor swarm missions and have a natural interaction with the control system. This service allowed the user to monitor and/or control real UxV via Virtual Reality (VR) and/or Augmented Reality (AR) user interface. The user was able to see UxV represented in 3D on an online 3D map and could monitor sensor values and choose to visualize streaming of sensors like cameras. Also, mission planning and execution were supported e.g. defining an endpoint for UxV. The system has been

built in modular architecture, which allows to make application to AR and/or VR version. Also, desktop and mobile devices were supported with limited features

IA3.2 DSL-based mission specification.

The objective of this innovation activity was to provide methods and tools based on a Domain Specific Language (DSL) for the description of robotic missions that were executed by the UxVs. This terminology was foreseen to cover all the aspects of a mission i.e., metadata (i.e. the name, the date, the number of nodes/swarms etc.), operation commands (statements for single node and swarm behaviour), event oriented commands (if-this-then-that) and post-operation commands (i.e. processing collected data). It should be noted that “typical” commands originated in traditional programming languages such as assignments, conditional statements (i.e., if, switch) and iterations (i.e., for-loop, while-loop) were also included.

IA3.3 Resource Controller.

The main objective of the activity is to provide a robust module that can generate, manage and supervise multiple missions at the same time, each potentially including multiple vehicles, operating autonomously and cooperatively in order to fulfil the missions’ high-level objectives. For this reason, a robust multi-threading mission management system and a novel multi-robot path planning algorithm were developed under this activity. The developed sub-system was extensively tested and validated, both in simulated and real-life operations, as a standalone service. It was integrated in the ROBORDER’s system and validated under simulated and real-world experiments in all of the system’s tests and demonstrations in order to deliver a TRL 7.

IA3.4 CISE-compliant common representation model and reasoning.

This activity focused primarily on providing the interoperability layer at the core of the platform to offer a unified representation of all pertinent contextual and threat related information, by developing and utilizing an ontology to describe the relevant concepts. Furthermore, the system aimed at enhancing the operator’s overall awareness, by aggregating the incoming multimodal data and detecting events, patterns and behaviours of interest and updating them. The service, acting as an alert mechanism, has been integrated as part of the first prototype and initially validated in the first Demonstration. TRL7 has been achieved during the second and the final trial showcasing the flexibility of the service under various operational scenarios

IA3.5 Risk models.

The purpose of this activity was to provide a software tool that will assist the short-term prediction of the spatial evolution of border related risks. This functionality allowed the system to early identify any change of the ongoing incidents e.g., the trajectory of an unauthorized vessel or the evolution of a hazard pollution incident. Risk models should consider data from sensors and constantly provide better estimations and forecasting. This activity should provide the software infrastructure required for an approach that may enable the easy integration of new models and risks.

IA3.6 Visual analytics and decision support.

The objective of the visual analytics included designing an advanced interface to provide data visualisations during pre, during and post-mission stages. The outcome developed, provided situational assessments during incidents, delivered key input in reviewing the success of past missions and staged the necessary analysis outcomes, to be applied to future missions, in order to improve the effectiveness of resources. This activity aimed to give the dashboard operators an overview of the situations and events that have passed or are occurring in real time, so that they can assess the corresponding threats and the severity level. It focused on providing contextual information while avoiding overload with excess information. This was possible through a layered visualization overview, a variety of charts and an intuitive map that could aggregate alerts that overlap. In addition, the decision support functionality has been integrated with the semantic reasoning model as part of the alert production mechanism towards an intuitive interface for the operator and support his/hers daily activities

1.2.1.4 ROBORDER platform development and integration

The implementation of the Final ROBORDER Integrated System was completed both from the software point of view, with the deployment of the system in the final architecture to be tested in the demonstrations and from the hardware point of view, with the deployment of the UxVs, physical server and communications system. All these activities are reported in D5.5 [RESTREINT UE/EU RESTRICTED].and the system has been evaluated successfully during the second and third demonstrations of the project.

1.2.2 User-oriented objectives

In order to ensure close relationship with the user activities a user-oriented approach was followed that based the aforementioned innovation objectives to the user-oriented objectives.

1.2.2.1 User requirements definition, end-user evaluation and validation

Aiming at defining an optimal and complete list of requirements, a template based on the Volere methodology that has been used with success in past projects, was introduced and parameterized to fit the purpose. This tool has facilitated the definition, the validation and the prioritization of the ROBORDER requirements. The template allows the administrator to control the status of the validation process from the initial definition to the final list of requirements passing through the required validation and revision status.

UA1.1 Use case creation and end user requirements definition.
The End Users employed expert committees, consisting of Subject Matter Experts, as well as members of Law Enforcement Agencies (LEAs) and/or Border Authorities, depending on the Use Cases' nature. Furthermore, these committees consulted with the consortium's Advisory Boards as well as the technical partners, either on a bilateral basis or by attending one or more of the technical workshops held in Thessaloniki, Greece and Brussels, Belgium; thus, ensuring that user requirements are consistent with ROBORDER's objectives and the partners' technical capacity.

UA1.2 Test case simulations and user evaluation.
For this user-oriented activity CMRE defined a validated set of project KPIs and qualitative evaluation tools and coordinated the organization of the live events needed to test and demonstrate the performances of the ROBORDER platform. The data collected during the tests are used to compute the KPIs, which is the quantitative grounding of the end-user, based evaluation of the ROBORDER platform. Furthermore, CMRE developed an M&S test bed capability to support the Concept development and Experimentation as well as the Verification and Validation of the ROBORDER platform. The capability has been used to support both end users and technical partners.

UA1.3 Human-robot concept of operations (ConOps).
The final version of the ROBORDER Concept of Operations (ConOps) was defined and presented in the D1.2 Annex Final Concept of Operations. The final ConOps provides an integrated and holistic view of how different actors, technologies, operating environments and related conditions establish an operating structure of autonomous robots for border control activities. In addition, the final ConOps considered the ROBORDER system features and technical structure and provided the generic and applicable model for ROBORDER use cases and system features. The Task also covers end user interviews related to the use case specific Concept of

Operations models. Task 1.5 Design of concept of operations for use cases has been completed.

1.2.3 Impact making objectives

The objectives and activities reported below was pursued in ROBORDER to develop key strategies for the exploitation of its main results, for exploring their wider use and sustainability as well as their business feasibility.

1.2.3.1 Dissemination and collaboration.

The main objective behind ROBORDER's dissemination and communication was to disseminate the project's progress and results to raise awareness around target groups as border authorities, LEAs and the security community, academia and SMEs. To fulfil this objective, a comprehensive dissemination strategy was envisioned to promote project activities, share knowledge and lessons learned within the scientific community. On the other hand, collaborations were foreseen via joint exploitation plans that allow partners to exploit the results to optimize their resources. Efficient collaborations included a shared action plan, and/or ownership of the project result in question.

IMA1.1 Dissemination of project results.
Synergies with other H2020 projects (ANDROMEDA, ARESIBO, CAMELOT etc.) at the area of border surveillance, comforts a good base of knowledge, exchange of information between all technical WPs. Consortium identified / targeted audiences (scientific experts, decision makers, potential end-users and LEAs at the domain of border surveillance/security) and achieved the maximum impact.
IMA1.2 Standardisation and collaboration with external bodies.
These activities concern the monitor and reporting on the use, within the ROBORDER project of (de facto) standards to enable the interoperability of all ROBORDER subsystems and third party elements that contribute to the multi-domain border security platform. Collaborations with other projects are also monitored and reported, with the aim of facilitating the project innovation, the exchange of knowledge and the application of best practices in the areas of security, surveillance and monitoring. Standardisation and collaboration with other projects are carried out by most project partners and coordinated under Task T7.3. The ROBORDER standardisation and external collaborations activities are illustrated with respect to their focus areas, domains, topics and types of activities, explaining their association with operational ROBORDER tasks. The data in support of this activity have been prepared with the collaboration of the reference ROBORDER partners.

1.2.3.2 Exploitation and sustainability model

According to the EC's guidelines for the dissemination and exploitation for Horizon 2020 projects, exploitation refers to the utilisation of results for commercial purposes or in public policymaking (European Commission, n.d). Those project results, or exploitable assets, could be software, hardware, publications, skills, or any other result developed during the project lifetime. Therefore, the Exploitation Plan and Sustainability Model presents partners' strategies to exploit the project results, as well as the collective actions to be taken towards the sustainability of the project.

IMA2.1 Market analysis for existing solutions.
Market analysis presented an overview of the most relevant market players and trends, which were essential for the successful deployment of ROBORDER. Structurally, market analysis clustered around three pillars: (a) Target market and

size; (b) User perception and; (c) Competitors analysis. The ***market size assessment*** was conducted through EU funding. EU's Internal Security Fund (ISF) channels €2.76 billion through shared management (European Commission, 2016). Other sources, include the police strand budget account for another €1 billion while €9.26 billion is allocated to asylum, migration and financing of agencies such as FRONTEX (European Parliament, 2016). Horizon 2020 programmes offer around 1.7 billion for border security improvement (European Commission, 2013). With respect to ***user perception***, after a survey conducted with the end-users based on a questionnaire the most important results was the following: The accurate real-time data collection capabilities provide better situational awareness, facilitating decision making, and increases overall efficiency of border surveillance. In addition, users perceived ROBORDER's capabilities to enrol in environmental missions as added value. Unmanned vehicles and mobile cameras could gather information to assist in prevention and detection of natural disasters, pollution levels, fires, floods, etc. Finally, a **competitors' analysis** was done based on a benchmarking tool that takes into consideration specific characteristics, such as the use of Augmented Reality (AR) and Virtual Reality (VR) technologies, recognition of illegal activities, and compatibility with UxVs and manned vehicles. Amongst results, it can be observed the absence of border security solutions compatible with swarms of UxVs, and the low presence of AR/VR technologies solutions in the market (10%). On the other hand, LEAs' utilisation, customisation, integration with current technologies and recognition of illegal activities are strongly present in the market and they are available in approximately 80% of border control platforms. This means that there is an opportunity for market penetration in AR/VR technology and Swarm of UxVs for ROBORDER. A simple comparison with similar platforms such as "Actacor", "BorderCore", "Border Control" and "Border Security" has shown that those cover 70% of ROBORDER's components. Overall, the results demonstrate that ROBORDER will bring additional border security specific components in comparison to other available solutions.

IMA2.2 Exploitation plans for the proposed tools.

The exploitation strategy aims to give a complete overview of the project results, identifying the innovation that has been developed in ROBORDER, the IP generated and how it will be protected. As such, the proposed exploitation plans from partners detail the strategies to use the results generated from the project, both individually and collectively. Exploitation plans are presented with respect to two dimensions: individual plans and exploitation collaborations. For individual plans, partners drafted their plans based on their specific situation. An individual plan contains detailed information about the exploitation of certain project result, including a description of the tool, type of exploitation (internal or external), reusability, ability to be monetised, users and the actions and details of exploitation. For exploitation collaborations, partners act together with different degrees of involvement to execute plans based on the collective interest, including a shared action plan, and/or ownership of the project result in question. The impact of this collaboration in exploitation has been measured and described in detail. Everis created a template, and assisted partners in gathering, treating, analysing and displaying the exploitation information, both at individual and collective level. Currently 66 individual exploitation plans and 20 exploitation collaborations have been gathered from the partners and have been included in D7.8 Exploitation Plan and Sustainability Model.

IMA2.3 Sustainable product to be integrated to LEAs environments.

Three sustainability models were proposed and discussed with the aim of ensuring the continuity of the project results. Each model considered a different approach to achieve long-term sustainability:

- The first model concerned the transfer of IPR governing the assets to an external organization with the interest and resources to ensure the exploitation and sustainability of the assets;

- The second model concerned the elevation of the assets to TRL 9, rendering the assets market-ready, by the consortium partners through funding obtained from external sources such as grants and loans;
- The third model concerned the division of selected assets into groups, which upon further development could independently lead to marketable solutions.

After careful deliberation, the second model was agreed upon by the consortium partners. Thus, partners were invited to propose their sources of funding which would be used to further develop ROBORDER assets. To provide support for the sustainability model, 23 calls for funding have been identified by partners, to potentially develop further the project results. In addition, 6 letters of intent have been collected from LEAs within the consortium as indications that end-users are interested in using the platform's components after the project, and applying them to their specific situation.

1.3 Summary of Results

By following the aforementioned approach and objectives, a number of key results have been identified regarding both long-term challenges and technologically mature objectives. These results and their readiness level are presented below.

1.3.1 Simulation Environment (SIMROB)

TRL1			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP2/ Adaptable sensing, robotics and communication technologies for different operational and environmental need

SIMROB reached the TRL targeted. The ELT simulation environment EWTISS has been adapted to cope with ROBORDER framework. Different assets, Platforms & sensors have been included (UAV, UGV, RF-Sensor, Radar….). SIMROB is ready to be used as test environment to assess the usage of the different assets planed within the ROBORDER framework (e.g. Path Optimization).

1.3.2 Extreme condition adaptability functionality

TRL2			WP/Obj.
Initial	Targeted	Current	
3	7	7	WP2/Re-configuration of agents and carrier solution

The adaptation of UGV/UAVs to extreme conditions was motivated by the diverse environmental conditions that may occur in borders and remote areas. Also, to increase the range of operation of small UAV a joint deployment and recharging method was required due to the short duration of UAV batteries. Work on this result was directed towards the development of a new autonomous UGV capable to carry a small. This UGV was developed starting with a commercial electric vehicle, which was modified to mount the appropriate sensors and actuators and equipped with autonomous navigation software. UAVs were adapted also to incorporate required sensors. A UAV/UGV joint development for recharging and landing platform was developed, which included a beacon-based landing method, together with an electromagnet-based attachment method. Adaptation was demonstrated for

UAV achieving TRL7 on second demonstration. UGV/ carrier solution could not be demonstrated during the second demonstration due to a malfunction of the UGV brakes which rendered the vehicle not operative during the second demonstration. However, UGV/Carrier solution was validated to a TRL5 in a laboratory environment

1.3.3 Passive radar receiver

TRL3			WP/Obj.
Initial	Targeted	Current	
4	7	7	WP2/Passive Radar on board UAVs and USVs

The motivation of developing the PR is to extend the coverage of the PRN developed by CNIT. The core value of this product is that the PR is portable, which can be used to harvest the electromagnetic echoes, which are too weak to be captured by the PRN. The PR consists of only a receiver used to detect and localise targets without its own transmitter but rather using pre-existing transmitters as illuminator of opportunity in this case the PRN in the Port of Livorno, Italy. Having only a receiver, the PR system is low cost to build and lightweight with low power consumption making it more suitable for mobile platforms such as UAVs, USVs and ultralight aircraft. The PR was successfully developed and fully tested in various trials during the development stage. In October 2020, the PR system was deployed using two transmitters, developed at the Fraunhofer FHR to replicate the PRN as the illuminators. The trial emulated the real scenario to detect targets namely a car over ground surface prior to the final demonstration where target was on the sea surface. The PR was able to detect and track the target successfully. The detection and tracking results were also successfully cooperated with the ROBORDER system via the MoniCA platform. That mean the experimental hardware and software of the PR are ready for real time deployment for the final operational scenario, which took place in the Port of Livorno. The real scenario operation during the latest trial and operational test proves that the system delivers a TRL 7 service.

1.3.4 Photonics-based radar

TRL4			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP2/Photonics-based radars WP3/Identification and tracking of illegal activities.

The architecture of the photonics-based distributed radar network has been defined, including the design of the central unit and of the remote radar heads. Each of these subsystems is composed of a photonic core (managing the up-conversion, distribution, down-conversion of the radar signals), that is interfaced to a digital part (for the generation and sampling of the signals at baseband, present only in the central office) and to an RF electronic part (for amplification and filtering of the RF signals, present only in the remote radar heads). The central unit also hosts the optical clock specifically developed by CSEM (see next paragraph). The deployment of the radar network in the port of Livorno has taken advantage of the fiber network already present there, but it has also required the installation of some new fiber spans to connect all the remote radar heads to the central unit. The activity has also included the development of the specific detection and tracking module. This makes use of the multiple acquisitions available from the radar network (exploiting both the geometrical diversity, i.e. the different viewpoints of the radar heads, and the frequency diversity, i.e. the different frequency bands used for the detections). Moreover, the software module also has the capability to exploit the intrinsic coherence of the radar signals to boost the resolution to hyper-fine level. The photonics-based radar network has been made communicating with the data infrastructure governing the port of Livorno, and from there with the ROBORDER platform.

1.3.5 Optical clock for photonics-based radar network

TRL5			WP/Obj.
Initial	Targeted	Current	
4	7	4	WP2/ Multi-static photonics-based radar network interoperable with existing infrastructure.

An optical clock based on a mode-locked femtosecond laser emitting a pulse train at a wavelength of 1560nm and with a repetition rate of 600MHz has been developed. First a laboratory laser was realized and showed the optical and metrological performance. Then a packaged laser was constructed, integrated in a rack together with the necessary electronics for a turn-key system. Indeed, the laser needs to be hand-free and to sustain shipment for instance. This turn-key system was delivered to CNIT and integrated in the photonics-based radar. The key challenges were linked to the packaging of the laser and a great deal of effort has been dedicated to figure out a technology that ensures the precise fixing of the laser cavity components. Indeed, the elements need to stay in place during the fixing and, very importantly, during the lifetime of the laser with a sub-micron precision. CSEM successfully solved these challenges and the turn-key laser routinely operates in the CNIT photonics-based radar.

1.3.6 Passive microwave sensors for mission-specific emission monitoring

TRL6			WP/Obj.
Initial	Targeted	Current	
5	7	-	WP2/RF signal sensor on board UxVs

The respective key result refers to the initial approach of the architecture where RF communications sensor would have been mounted on UxVs. The objective involves the use of TEK-AS SDR-based platform for identifying illegal communications which after the beneficiary's termination, the architecture adopted another approach that has been aligned and merged with Result described in Section 1.3.14.

1.3.7 Hierarchical cloudlet-based communication architecture

TRL7			WP/Obj.
Initial	Targeted	Current	
3	7	-	WP2/Cloudlet based communications

The respective key result refers to the initial approach of the architecture where a cloudbased architecture would have been applied. Nonetheless, after the assessment of the end-user requirements and the decision of a local deployed system, these Key Results are invalid. Considering also the termination of TEK-AS as the main contributor, these TRLs are obsolete.

1.3.8 Context-aware link selection algorithm

TRL8			WP/Obj.
Initial	Targeted	Current	
3	6	-	WP2/RF signal sensor on board UxVs

The respective key result refers to the initial approach of the architecture relevant to the identification of the RF-based intrusions. Similarly, to Section 1.3.6, the objective involves the use of TEK-AS SDR-based platform for identifying illegal communications which after the beneficiary's termination, the architecture adopted another approach that has been aligned and merged with Result described in Section 1.3.14.

1.3.9 Moving target detection

TRL9			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP3/Identification and tracking of illegal activities, WP6/Marine border threats detection.

Regarding the detection and tracking of possibly harmful moving targets, during the PUC 1.6 operational test in Livorno, the photonics-based radar network and the passive radar performance have been tested against a small cooperative speedboat used as target of reference. Despite the environmental limitations, the achieved performance has been very close to the targeted benchmark values.

1.3.10 Event detection and recognition

TRL10			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP3/Detection of pollution incidents

In the scope of Task 3.1, the pollution incidents detection module was motivated by previously presented methods focused on fundamental computer vision techniques. Yet, the deployed module relied on a deep-learning approach for image semantic segmentation, aiming to increase the detection accuracy and its capability to extract semantic information. Towards this direction, a dataset containing SAR images depicting oil spills over sea surface was generated to train and evaluate the model to fulfil a value of TRL5. The deployed module was further extended to process visual cues, apart from SAR images. More specific, a preprocessing pipeline was built in order to transform the visual input to a SAR-like image representation, before forwarding it to the detection model. The updated framework was integrated in the overall system leading to a functional service for oil spill pollution detection. The service was efficiently validated in the scope of the 1st demonstration achieving level TRL7. Nonetheless, due to environmental safety issues and regulations, the validation of the service was performed using simulated oil slicks created by dispersed rhodamine (as the creation of an environmental disaster under real conditions is prohibited) and detected with the use of visual data. Within the scope of Task 3.2, the visual object detection model relied on well established methods which were mostly validated under laboratory conditions. Yet, novel approaches have been incorporated towards increasing the robustness, versatility and effectiveness of the model under real conditions. A new training dataset has been compiled using both public and private sources, the latter especially in the cases the public datasets were not sufficient enough to reach the project's goals. The stand-alone object detector was incorporated with a highly efficient tracker to embody visual tracking capabilities to the framework. Various mechanisms have been utilized to prevent false positives and increase effectiveness exploiting the presence of those two complementary algorithms. The service has been thoroughly evaluated during the 2nd and 3rd demonstrations under real conditions and achieved a TRL7 level performance.

1.3.11 Activity detection and recognition

TRL11			WP/Obj.
Initial	Targeted	Current	
4	6	6	WP3/Identification and tracking of illegal activities

The activity detection components pulled to meet the gap between visual inputs and raising activity alert events and provide a strong use case at TRL 6. To fulfil this gap, the key effort involved the processing of real environmental visual inputs across multiple sources. The detection model was required to make the links between different visual detections and activity recognition outcomes across several use-case scenarios. The component was integrated into the system framework as a pipeline, used during the 2nd and 3rd demonstrations taking visual detections produced by deep-leaning models and running tracking and indication algorithms to reach a threshold for an activity event alert to be sent on to the decision support.

1.3.12 Low-level fusion engine

TRL12			WP/Obj.
Initial	Targeted	Current	
3	5	5	WP3/Low level fusion of sensor data

The initial development of the "*fusionData*" component involved the combination of image representations acquired under the visual spectrum with the corresponding images under the IR spectrum. Each sensor provided an input to the implemented module, which merges the two same scene representations under different spectra. The approach has been validated under laboratory conditions meaning using publicly available datasets in the scope of implementing an integrated prototype. Nonetheless, "*fusionData*" module has been updated during the last reported period following a different approach due a number of limitations with respect to the camera setups. Within this context, a low-level fusion technique (JDL-0) has been developed, combining data collected from heterogeneous sensors (i.e., telemetry data, GPS, IMU devices etc.) aiming at improving the estimated location of the asset that identifies and event. Due to these hardware related restrictions, the latter fusion approach has been selected to be validated during the last phase of system integration, by directly comparing the output of the "fusionData" module with the path obtained by the mission planning module and the measured (real) path. The service has been validated using previously collected data provided by the corresponding partners in similar operational scenarios and in relevant environments reaching TRL5.

1.3.13 Intrusion detection and classification module

TRL13			WP/Obj.
Initial	Targeted	Current	
4	6	6	WP3 / **IO2** Detection and identification of border-related threats / **IA2.4** Detection framework for recognising cyber and

			cyber-physical attacks (KR: Intrusion detection and classification module)

The intrusion detection and classification module (IDCM) was inspired by previously presented methods focused on increasing the situational awareness of autonomous agents (UxVs) by detecting cyber and cyber-physical attacks against them. Yet, the deployed module relied on a combination of a statistical-based reasoning and deep learning-based reasoning approach, aiming to increase the detection accuracy of the module and its capability to detect the root of the anomaly in an automated way. Towards this, proper datasets containing telemetry data from the autonomous agents were gathered during the weekly dry runs to train and evaluate the model and fulfil a value of TRL5. The deployed module was further extended to detect anomalies for several autonomous vehicles at the same time (e.g., UAV, UGV, UUV) and provide a run-time solution for multiple live stream data sources. The updated framework was integrated in the overall ROBORDER system leading to a functional service for intrusion detection and classification. The service was efficiently validated in the scope of the operational test PUC2.1 that was conducted during the 2nd demonstration achieving TRL6. Due to integration-related issues, the validation of the service was performed offline using the telemetry data captured during the jamming attack against the ROBORDER's UGV at the Bulgarian demo site.

1.3.14 SDR-based sensor of unauthorized RF communications for use on board unmanned vehicles

TRL14			WP/Obj.
Initial	Targeted	Current	
4	6	6	WP2/ Adaptable sensing, robotics and communication technologies for different operational and environmental need.

The RF sensor (ELT) reached the TRL targeted. ELT did also implement the detection and identification of unauthorized UAV communication in the SDR-based sensor. The results have been forwarded to ROBORDER framework and displayed in the Dashboard. The integration of the sensor on the TEKEVER UAV could not be realised. As agreed with the consortium the prototype has been built to fit into the UGV of ROBOTNIK.

1.3.15 Novel Human-UxV interface

TRL15			WP/Obj.
Initial	Targeted	Current	
3	6	6	WP4/Novel Human – Robot interface exploiting VR/AR

Development of novel human-robot interface was following the main principles of Human Centred Design. The first version – proof of concept was developed in early stage of the project – TRL3. This version was used for collecting user feedback and preliminary requirement for the advanced human-robot interface. Based on the user feedback, the first function prototype was development – TRL5. The first functional prototype was the basis of laboratory evaluations. Usability evaluation, observation and interview results was guiding the development of the integrated version of the advanced human-robot interface – TRL6.

The service was efficiently validated in the scope of the demonstrations. More details of the service could be found in D4.1 [RESTREINT UE/EU RESTRICTED].

1.3.16 UxV Virtual Controller

TRL16			WP/Obj.
Initial	Targeted	Current	
3	7	7	WP4/Generation and management of autonomous multi-robot missions

The Autonomous Resource Task Coordination module was based as a concept on previous EU projects (e.g., NOPTILUS and RAWFIE). The concept was to provide a tool able to receive high-level defined objectives for a mission, defined by a single human supervisor, and translate it to specific, low-level guidelines, tasks and actions for each of the involved assets, in order to cooperatively achieve the defined objectives. The delivered module incorporates a novel multi-robot path planning algorithm, developed specifically for the needs of the project, guaranteeing state-of-the-art performance, increased operational efficiency, resource management and operational safety. Through the continuous development and validation cycles during the project, the developed system managed to achieve a TRL 7, reaching the initially expected and targeted value.

1.3.17 “Plug-n-play" Resource Controller

TRL17			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP4/Plug-n-play autonomy platform for autonomous swarm operations

The Autonomous Resource Task Coordination module got developed in a way that allows the incorporation of any type of unmanned (or even human operated) vehicles and assets in a mission, in order to succeed the high-level human defined objectives. It supports the simultaneous operation of different types and models of vehicles, with different specifications and operational capabilities, without limiting the operational efficiency due to possible assets’ incompatibilities. The plug-n-play nature of the module got tested and validated through a series of simulated and real-life experiments and managed to achieve the targeted TRL value of 7.

1.3.18 Mission authoring tool

TRL18			WP/Obj.
Initial	Targeted	Current	
4	7	7	WP4/ DSL-based mission specification

In the context of ROBORDER, a dedicated tool to support functionalities related to the definition of missions in terms of unmanned vehicles movement and their undertaken actions has been developed. The tool was based on existing efforts carried out in the context of H2020 RAWFIE project where a graphical tool for the management of remotely executed research experiments involving drones has been implemented. In the context of ROBORDER, this tool was expanded to fulfil the needs of border management operations and demonstrated in such environments.

1.3.19 CISE-compliant common representation framework

TRL19			WP/Obj.
Initial	Targeted	Current	
3	6	7	WP4/ CISE-compliant common representation framework]

In order to achieve interoperability and data integration from multiple sources, the EUCISE2020 data model was used as the baseline for the ROBORDER ontology. The outcome was the EUCISE-OWL, an ontology implemented in OWL 2 which specifies a common information sharing environment that is imported in the ROBORDER ontology. The latter comprises a vocabulary, capable of describing the pertinent to the project classes and concepts and semantically represent the PUCs. Assessing the operational scenarios that the framework requires to cover, the deployed ontologies receive the detection outcomes as well as raw data from specific sensors and described the detected event in a comprehensive to the end-users format. The initially targeted TRL was identified to be equally to TRL6. Nonetheless, the service has been validated as part of a demonstrated prototype in three different operational environments accomplishing a delivered value of TRL7.

1.3.20 High-level integration, reasoning and interoperation framework

TRL20			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP4/ High-level integration, reasoning and interoperation framework

For the needs of the task, the Knowledge Base Service was implemented. This has two parts, the populating and the reasoning subservice. The Knowledge Base service is consuming data from sensors e.g. from radar and information from other modules of the system e.g. the object detector and by semantically annotating them they are fused, integrated and stored in a graph, triplestored for further analysis. Furthermore, by applying rule-based reasoning techniques the Knowledge Base Service can detect, infer and provide high-level alerts to the system. Operating as part of an entire mechanism of alert production and filtering, the service has been validated under the scope of a demonstrated prototype in all operational trials reaching the foreseen TRL7.

1.3.21 Dynamic data-driven assimilation toolkit

TRL21			WP/Obj.
Initial	Targeted	Current	
6	7	7	WP4/Risk Models

ROBORDER Risk Models module implemented a framework for the easy integration of risk models incorporating methodologies already adopted by the practitioners. In particular, this module provides the necessary software infrastructure for the integration of forecasting models that can be used for assessment of border security risks. The module is based on the Frontex Common Integrated Risk Analysis Model methodology (CIRAM) for risk evaluation. The CIRAM terminology is adopted for the characterization of risks to formalise and assess potential threats at tactical and operational level. A set of predictive models have also been integrated to support forecasting.

1.3.22 Decision support module

TRL22			WP/Obj.
Initial	Targeted	Current	
5	7	7	WP4/Decision support module

The decision support is designed to assist the command and control unit by offering aggregated information and combined alerts. These increase the overall awareness and aid the process of decision making through the fast and accurate situational overview that the support decision module offers. The alerts contain information regarding the detections and events, and depending on their type, they describe their status, speed, timestamp, their geospatial and temporal context, the risk prediction and a computed severity level to assist and advance the operator's decision making. Part of the alert production mechanism, the decision support module has been validated under various operational tests and in the scope of a demonstrated prototype during the foreseen trials reaching the foreseen TRL value of 7.

1.3.23 Visual analytics module

TRL23			WP/Obj.
Initial	Targeted	Current	
3	6	6	WP6/Visual analytics and decision support

The visual analytics module came from the conceptual need for ROBORDER to have a place to review the data generated by various systems in a visual way. As a result, the platform would be able to make situational assessments from the detailed analysis of information that can be conducted on various sets of data. The resulting module exhibits the need for analysis of real data generated on every mission scenario as demonstrated in an operating environment across all three demonstrations supporting the analysis of data generated by pollution detection and illegal activity missions aligning to the target TRL 6. The subsequent interface allowed dynamic navigation of map and non-map data to view visual aggregation outcomes of several missions for the benefit of improving the operational performance of future planned missions relating to the routes taken, times of day to conduct missions, and mission and vehicle frequencies, using the time range or mission-based interactions.

1.3.24 Integrated and functional system

TRL24			WP/Obj.
Initial	Targeted	Current	
3	7	7	WP5/ROBORDER system integration

The integrated and functional system consists of two types of software components; the first type is in charge of the mission design and decision support and the second detects and identifies threats. The software system interacts through a message bus with the hardware system deployed in the operating area and represented by ground control stations (GCS) controlling unmanned vehicles. The synergy of the two systems represents the entire ROBORDER system. These software components are deployed in a physical server that is communicated with the other assets through local secure RF communications, without the use of the internet. In preparation for the demonstration of the ROBORDER system in real environments. A value of TRL4 was validated during test sessions conducted in a virtual environment and using simulated data. Subsequently, the system was deployed in three different environments as part of the three demonstrations. During the demonstrations, software and hardware components were fully integrated into the ROBORDER system and tested in real condition to achieve a value of TRL7.

2. Data Management

This section provides an overview of the Data Management Plan (DMP) that was followed until the end of the project and has been firstly reported in this form in deliverable D8.4 – Self-assessment and data management plan V2, submitted in Jan. 2021 and it follow EC's fair principles[1] [1]. The content found in the table found are still considered relevant and can be found below with some minor updates that took place in the final period of the project based on the experiences of the involved partners and the lessons learnt.

DMP Component	Issues to be addressed
Data summary	**Purpose**: The data collected before the execution of the demonstrations through the informed consents/questionnaires aim at ensuring that the involved people have the experience and expertise to provide the consortium with some insightful feedback regarding the system and its successful operation. Additionally, the participant's signature and **basic personal information** (name, age, etc.) were used for filling in of the informed consent that all human research participants should sign before their involvement in the study. Morover, the **data collected from the demonstration site** by the UxVs that were operated contributed to the evaluation of the sensors and cameras performance and the assessment of its capabilities in order to ensure the detection of object of interests on site as well as the system's interoperability. **Relation to objectives**: ⇒ IO1: Adaptable sensing, robotics and communication technologies for different operational and environmental needs, ⇒ IO2: Detection and identification of border-related threats, ⇒ IO3: Tele-operation of autonomous agents through a 3D user interface and decision support, ⇒ IO4: ROBORDER platform development and integration, ⇒ UO1: User requirements definition, end-user evaluation and validation, ⇒ IMO1 Dissemination and collaboration, ⇒ IMO2 Exploitation and sustainability model **Types and formats**: Regarding the data that were collected before and during the demonstrations/operational tests, the informed consent with the participants basic personal data were kept in file both in a hard copy and a digital (scanned) form. The data collected from the UxVs were mainly images and footages from mostly RGB cameras while sensory values from the RF sensor and the photonics radar infrastructure were separately collected and processed. Additionally, telemetry data and system diagnosis data (such as altitude, airspeed, position etc.) were collected following a common data representation model for all the integrated components **Re-use of existing data**: During the implementation of the detection algorithms, multiple open access databases have been used (e.g., Pascal-VOC). These databases mostly referred to visual data and deployed algorithms and helped with the training and testing of the

[1] Available online at: https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf

DMP Component	Issues to be addressed
	detection models that are going to be used by ROBORDER. **Origin**: All involved partners with the necessary expertise generated ROBORDER's dataset during the demonstrations/operational tests that took place from M35 onwards. **Size**: The size of the processed data could not be identified as it depends on various system parameters (e.g., resolution of the images, mission time etc.) Different durations and different levels of complexity for each scenario also affected the total size of the collected data. Though, a rough estimation for the 2nd and the 3rd trial might be approximately 20 GB and 13 GB, respectively, including footages and images that presents the overall activities. **Utility**: The prementioned dataset is crucial importance to the entire consortium in regard to achieving ROBORDER's objective. In addition, this information could also prove beneficial for future researchers who wish to delve into border security state-of-the-art, as well as potential stakeholders that are interested in ROBORDER's technologies.
FAIR Data - Findable	**Discoverability**: The ROBORDER datasets (e.g., ROBORDER ontology for marine data annotation) are going to be made discoverable through its association of the metadata related to the dataset, mainly focusing on date of measurement, target classification, time of measurement and location of measurement. **Identifiability**: All data collected during the project's lifetime will be assigned to a unique and persistent identifier which is linked to the EU cordis portal (https://cordis.europa.eu/project/id/740593/en) and will be enriched with metadata that will be able to give detailed information regarding the context and the quality of the data. **Naming conventions**: The general scheme that was agreed by the consortium for naming the data is as follows: ROBORDER_PUCx_Location_Sensor_No_Version_file.exension, where "PUCx" is the number of the executed Pilot Use Case, "Location" corresponds to the location that the demonstration/operational test was performed, "Sensor" indicates the type of sensor, "No" presents the number of streaming data and "Version" is for the version of the file. **Search keywords**: The main approach regarding the search keywords aims at high specification and relevance. For example, in the first PUC that was performed in Portugal, the appropriate keywords for searching relevant information was "Portugal demonstration" and not "demonstration" in general. The same approach was followed for the remaining two demonstrations in Bulgaria and Greece. **Clear versioning**: A manual version is going to take place for the finding of ROBORDER's data. The initial version will be "0.1" and after the commencement of any update or change, the involved partner will make sure to update the version of the file with the number to follow (e.g., 0.2). **Metadata creation standards**: OpenAIRE Guidelines for Data Archives (here).
FAIR Data – Accessible	**Openly available**: The data that contributed to enhancing ROBORDER's detection technologies and capabilities will be openly available to the consortium through secure channels such the

DMP Component	Issues to be addressed
	established wiki page. The only data that will not be distributed to the partners will be the participants' personal data (such as name) in order to protect their privacy. The outcomes of the demonstration or the participant's feedback can become available to the rest of the partners, only after it has become anonymized. Outcomes and findings derived from the process and analysis of the aforementioned (anonymized) data will be widely available to the scientific community through scientific publications in Conferences, Journals, and Scientific Magazines. These publications will be available via OpenAire (here). **Tools and means of availability**: The main tool for exchanging data will be the ROBORDER's wiki page (Link) that has been created by CERTH for collaborating purposes. All involved partners have a unique set of username and password in order to log in and find the data they need in the respective sections. For EU_RESTRICTED data, a ZED! encryption software is required in order to successfully encrypt sensitive information. Openly accessible data will be available through OpenAire (with the scientific publications). **Deposition**: The consortium ensures that all the measures will be considered to secure all the acquired data as well as all the products of developments (e.g., code). For example, the acquired data processed during the execution of the pilot use cases were stored on a secure server of EVADS. **Provision of access** (in case of restriction): As mentioned above, all partners have access to the project's wiki page that has been created by CERTH; a personalized username and password was created for each individual to secure the means of collaboration. In case of information that is considered RESTREINT UE/EU RESTRICTED, the person requesting access should have the "need to know" and abide by COMMISSION DECISION (EU, Euratom) 2015/444 of 13 March 2015 on the security rules for protecting EU classified information[2][2].
FAIR Data – Interoperable	**Assessment of interoperability**: The collected and generated data were provided to the partners in standard formats in order to ensure their interoperability in multiple systems. For example, for images a JPG and BMP formats were opted for. **Vocabulary and ontologies**: Towards providing increased situation awareness to the operators, a CISE-based ontology was developed to describe efficiently the detected events. In addition, CIRAM data model was exploited as a risk model integrated to the framework.
FAIR Data – reusable	**License**: All collected/generated data are open to the consortium for re-use until the project's end date. After that, ROBORDER will attempt to ensure its dataset's widest reusability with the anonymized research findings that have been included in the publicly available reports and scientific publications. This will not apply to the personal information (e.g., names and email addresses) collected through the informed consents prior to the execution of the demos, as they cannot be reused for other purposes other than the ones stated in the information sheet provided to the data subject. In the case of the ROBORDER ontology for marine data annotation, since this information cannot be open source (as it was based on the scenarios provided by ROBORDER's end user partners and are considered

[2] Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2015_072_R_0011&qid=1427204240846&from=EN

DMP Component	Issues to be addressed
	EUCI, reusability can be ensured with the provision of access to interested parties that are compliant with the "Provision of access" as described in the "FAIR Data – Accessible" section above and the "Third parties" section right below. **Third parties**: Third parties will be able to reuse the data produced by ROBORDER, which could be found anonymized in publicly available deliverables, reports and scientific publications. This will not apply to EU RESTRICTED information, unless the third party can prove compliance with COMMISSION DECISION (EU, Euratom) 2015/444 of 13 March 2015 on the security rules for protecting EU classified information. **Quality assurance**: Before providing the acquired/generated data available to the rest of the involved partners via wiki, the responsible partner (i.e., partner responsible for the demo execution or partner responsible for the collection of the on-the-field data from the UxVs) should make sure that they are accurate and complete. They should always follow the naming and versioning that has been indicated and upload the data in their respective section in wiki, so they can be easily found by the rest of the involved partners. In addition, they should ensure that they are providing the data in a correct format and in the correct form (as a plain file or encrypted) depending on the type of information. **Re-use duration**: Currently, the original datasets that are created after the demonstrations/operational tests are available for re-use among the consortium until the project's end date. After its completion, anonymized data will remain available for reuse through the publicly available reports and publications.
Allocation of resources	**Estimation of costs**: The consortium internal (data) management tool, wiki, requires no resources; however, the encryption software ZED!Pro that is needed for exchanging sensitive data should be purchased by all partners. This cost was already foreseen in the original budget allocation. **Responsibilities**: All partners should make sure to abide by the updated DMP set out in this deliverable and purchase the needed tools and means in order to properly handle the produced data. CERTH is the main responsible for overseeing the DMP's implementation as the project's coordinator. **Long-term preservation**: Non anonymized and/or sensitive collected data will be preserved for 5 years after the completion of the project for auditing purposes. This data is to be safely stored in CERTH's servers located in its premises and partners will have access to them through the collaborative management tool (wiki). Anonymized data that will be used for publications will be preserved based on the policies followed by the repository of choice that they will be uploaded.
Data security	ROBORDER's dataset does not include any sensitive or restricted data and all personal data and identifiers will be anonymized before being incorporated. Being stored in wiki, access is granted only to the individuals that have been given their unique pair of username and password by the coordinator; therefore, an intrusion or a breach is mitigated. Additionally, a specific versioning of the data will be followed which will allow access to the item's history to restore any kind of information, in case of an incidental deletion. This is also applied to wiki's functionalities, which allows the restoration of deleted

DMP Component	Issues to be addressed
	information. Finally, the exchange of sensitive data among the partners and between the consortium and the EC will be conducted with the use of an encryption software (ZED!).
Ethical aspects	ROBORDER's ethical aspects are described in the submitted WP9 deliverables, in the updated ethics related deliverable D8.6, which addresses all issues indicated by the ethics committee as well additional ethics focused documents that were submitted to the project's Officer. Updated information regarding their data collection and processing have been requested by the partners involved in the PUCs and copies of ethics approvals have granted by multiple partners in the Consortium. The remaining partners that did not have the capacity to acquire an ethics approval from an independent and competent ethics committee had to show a detailed data protection/privacy/ethical compliance policy that they follow in order to ensure that human participants in the project's studies will be safeguarded. All the required authorizations for operating UxVs in the demonstration/operational test areas have been acquired and signed informed consents were collected before commencement of any relevant work when humans were involved. The process was monitored by an External Ethics Advisor who guided all partners through the process and provided detailed reports on the project's ethical progress.

Table 2: Data Management Plan

2.1 Intellectual Property (IP)

The intellectual property is withing the context of the deliverable D7.8 that has as a submission date the 31st of August 2021. For more information about the intellectual property refer to D7.8.

3. Self Assessment

The following section includes all the relevant information for the assessment of individual tasks within the WPs from the perspective of the objectives that were foreseen to be fulfilled. The Gantt chart in Figure 1 represents the time plan of the project in relation to submission dates of deliverables and milestones achievement.

ROBORDER					
	WP/Task name	Leader	Start Month	End Month	Duration (Months)
WP1	User requirements and pilot use cases	HMOD	1	47	47
T1.1.	Analysis of user requirements and operational aspects	HMOD	1	47	47
T1.2.	Analysis of security requirements	BDI	1	47	47
T1.3.	Analysis of ethical and legal requirements	ORFK	1	47	47
T1.4.	Design of the pilot use cases	HMOD	1	47	47
T1.5.	Design of concept of operations for use cases	VTT	1	47	47
WP2	Sensing, robotics and communication technologies	ELLETRONICA	1	33	33
T2.1.	Cloudlet based communications	TEK-AS	1	12	12
T2.2.	Passive radar on board UAVs and USVs	FHR	1	33	33
T2.3.	RF signal sensor on board UxVs	ELLETRONICA	1	33	33
T2.4.	Sensors adaptability	ELLETRONICA	1	33	33
T2.5.	Re-configuration of agents and carrier solution	ROBOTNIK	1	33	33
T2.6	Photonics-based radars	CNIT	3	33	31
WP3	Detection and identification of border-related threats	CNIT	1	38	38
T3.1.	Detection of pollution incidents	CERTH	1	35	35
T3.2.	Identification and tracking of illegal activities	CNIT	1	35	35
T3.3.	Low level fusion of sensor data	CERTH	1	35	35
T3.4.	Detection and classification of cyber and cyber-physical attacks	CLS	1	38	37
T3.5.	Identification of unauthorized communications using RF sensor	EVADS	3	38	36
WP4	Command and control unit functionalities	CERTH	3	38	38
T4.1.	Advanced Human-Robot interface	VTT	3	35	33
T4.2.	DSL-based mission specification	UoA	3	35	33
T4.3.	Autonomous resource task coordination	CERTH	6	35	30
T4.4.	CISE-compliant common representation model and semantic reasoning	CERTH	3	38	36
T4.5.	Risk models	UoA	3	38	36
T4.6	Visual analytics and decision support	CERTH	6	38	33
T4.7.	Command and Control Unit	EVADS	24	38	15
WP5	Integration of ROBORDER platform for the remote assessment of border threats	CERTH	1	50	50
T5.1.	Technical system requirements and architecture	TEK-AS	1	12	12
T5.2.	Software integration	EVERIS	10	48	39
T5.3.	Hardware integration	EVADS	10	48	39
T5.4.	ROBORDER System integration	EVADS	11	50	40
T5.5.	System deployment and maintenance in testing environment	EVADS	18	50	32
WP6	Demonstrations and evaluation	CMRE	1	51	51
T6.1.	End-user evaluation plans and methodology	CMRE	1	38	38
T6.2.	Operator training	ORFK	5	51	47
T6.3.	Preparation and implementation of test-plans as simulated exercises	CMRE	13	50	38
T6.4.	Demonstration and evaluation for marine border threats detection	GNR	19	51	33
T6.5.	Demonstration and evaluation for land border threats detection	BDI	19	51	33
WP7	Dissemination and exploitation	EVERIS	1	52	52
T7.1.	Dissemination and events organisation	HMOD	1	52	52
T7.2.	Communication	CERTH	1	52	52
T7.3.	Standardisation and collaboration with other projects	CMRE	1	52	52
T7.4.	Market analysis	EVERIS	3	14	12
T7.5.	Business model	EVERIS	14	52	39
T7.6	Exploitation and long-term sustainability plan	EVADS	14	52	39
WP8	Project management	CERTH	1	52	52
T8.1.	Project management	CERTH	1	52	52
T8.2.	Project administration, reporting and financial management	CERTH	1	52	52
T8.3.	Quality assurance and risk management	CERTH	1	52	52
T8.4.	Management of confidential information	CERTH	1	52	52
WP9	Ethics requirements	CERTH	1	52	52
T9.1.	H – Requirements No. 5	CERTH	1	52	52
T9.2.	POPD – Requirements No. 6	CERTH	1	52	52
T9.3.	POPD – Requirements No. 10	CERTH	1	52	52
T9.4.	OEI – Requirements No. 14	CERTH	1	52	52
T9.5.	DU – Requirements No. 15	CERTH	1	52	52
T9.6.	GEN – Requirements No. 19	CERTH	1	52	52
T9.7.	Ethical Code and Updates on Data Protection	CERTH	1	52	52
	Milestones				

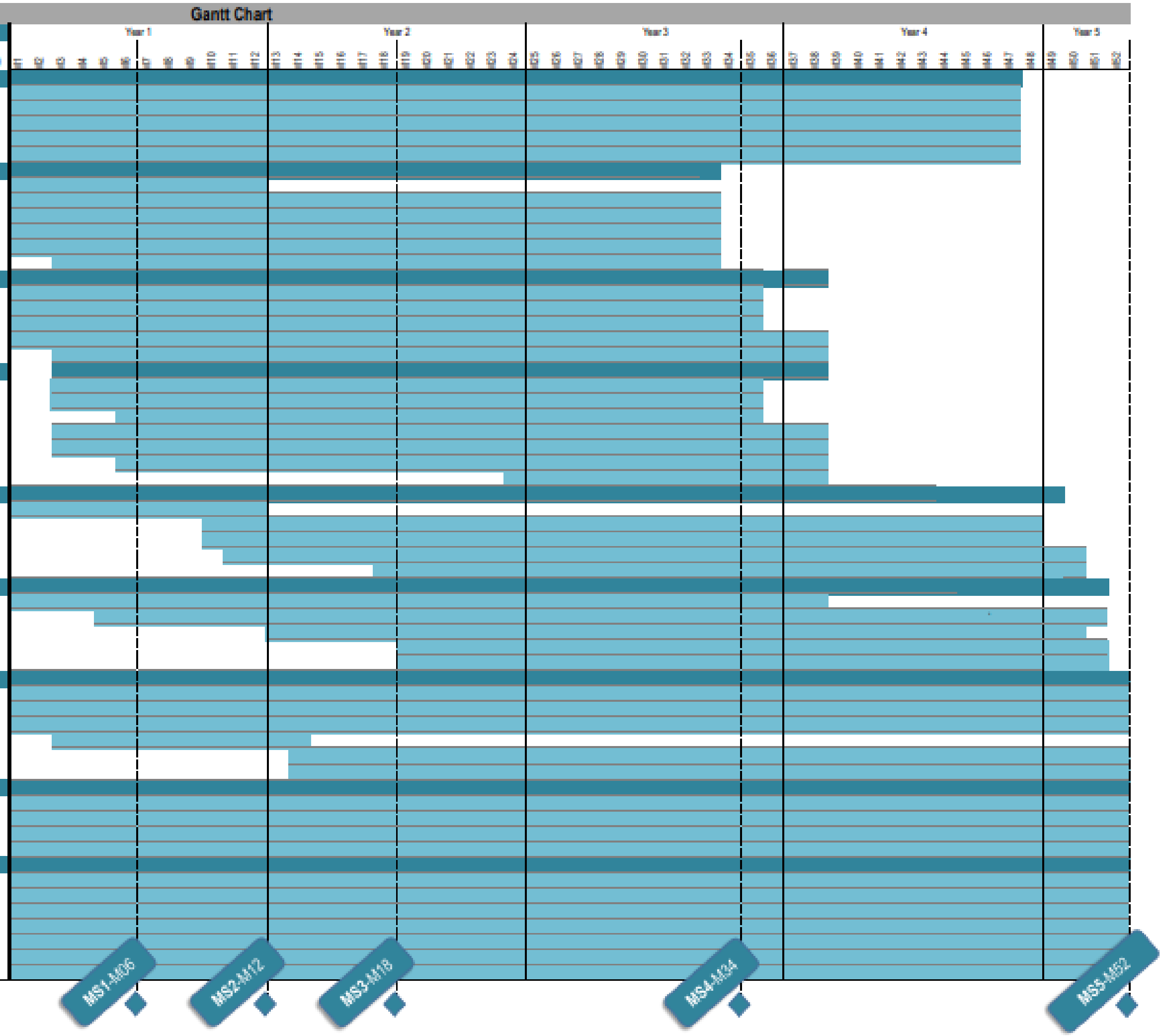

Figure 1 - Gantt chart

During the lifetime of the project all 45 planned deliverables were submitted according to Table 3. Most of the deliverables were submitted on time or in compliance with the guidelines of the Project Officer, when on time submission was not possible.

No	Del	Title	Author	Dissemination level	Due date	Submission date	Status
1	D7.1	Dissemination plan	HMOD	Public	31/07 /2017	12/01/2018	Submitted
2	D7.2	ROBORDER Website and communication material	CERTH	Public	31/07 /2017	31/07/2017	Submitted
3	D8.1	Project management and quality assurance plan	TEK	Public	31/07 /2017	31/07/2017	Submitted
4	D9.3	POPD – Reuirement No. 10	CERTH	Consortium Confidential	31/07 /2017	15/12/2017	Submitted
5	D5.1	Technological Roadmap	TEK	EU_RES	31/10 /2017	22/12/2017	Submitted
6	D6.1	Evaluation Methodology	CMRE	EU_RES	31/10 /2017	14/10/2019	Submitted
7	D8.2	Self-assessment and data management plan V1	TEK	Public	31/10 /2017	22/12/2017	Submitted
8	D9.4	OEI – Requirement No. 14	CERTH	Consortium Confidential	31/10 /2017	13/11/2017	Submitted
9	D8.3	Mid-term review and progress report	TEK	Public	31/10 /2018	30/11/2018	Submitted
10	D2.1	Communication architecture report	TEK	EU_RES	30/04 /2018	13/08/2018	Submitted
11	D2.2	Performance assessment of ROBORDER configurations	ELTM	EU_RES	30/04 /2018	03/10/2018	Submitted
12	D5.2	Technical requirements and operational architecture	TEK	EU_RES	30/04 /2018	12/06/2020	Submitted
13	D9.1	H – Requirement No. 5	CERTH	Consortium Confidential	30/04 /2018	09/05/2018	Submitted
14	D9.2	POPD – Requirement N0. 6	CERTH	Consortium Confidential	30/06 /2018	09/05/2018	Submitted

15	D9.5	DU – Requirement No. 15	CERTH	Consortium Confidential	31/07/2018	09/05/2018	Submitted
16	D7.3	Market Analysis	EVERIS	Public	31/10/2018	05/11/2018	Submitted
17	D6.2	Action plan for PUC	CMRE	Public	31/10/2018	07/08/2018	Submitted
18	D1.1	Draft of Concept of Operation, Use Cases and Requirements	HMOD	EU_RES	31/10/2018	17/10/2019	Submitted
19	D5.3	First integrated ROBORDER system	TEK	EU_RES	31/10/2018	08/06/2020	Submitted
20	D6.3	First M&S based Test Bed Demonstration	CMRE	EU_RES	31/10/2018	07/12/2018	Submitted
21	D6.6	First Evaluation report	CMRE	EU_RES	31/10/2018	31/10/2018	Submitted
22	D7.4	Mid – project Dissemination Reports	HMOD	Public	31/10/2018	05/11/2018	Submitted
23	D9.6	GEN – Requirement No. 19	CERTH	Consortium Confidential	31/10/2018	05/11/2018	Submitted
24	D2.3	Final Sensors Implementations	ELTM	EU_RES	31/01/2020	31/01/2020	Submitted
25	D2.4	Adaptability solutions for robotic platforms	ROB	EU_RES	31/01/2020	31/01/2020	Submitted
26	D8.4	Self-assessment and data management plan V2	CERTH	Public	31/01/2020	31/01/2020	Submitted
27	D5.4	Second integrated ROBORDER system	CERTH	EU_RES	29/02/2020	30/03/2020	Submitted
28	D6.4	Second M&S based Test Bed Demonstration	CMRE	EU_RES	31/03/2020	01/06/2020	Submitted
29	D8.6	Ethical Code and Updates on Data Protection	CERTH	Consortium Confidential	31/03/2020	28/04/2020	Submitted

30	D3.1	Event and Activity Detection and Recognition	CERTH	EU_RES	30/04 /2020	11/05/2020	Submitted
31	D4.1	UxVs teleoperation framework and interface	CERTH	EU_RES	30/04 /2020	11/05/2020	Submitted
32	D3.2	Intrusion and illegal communicati ons detection	CLS	EU_RES	30/06 /2020	30/06/2020	Submitted
33	D4.2	Visual analytics and decision support tools based on risk models and reasoning methods	CERTH	EU_RES	30/06 /2020	30/06/2020	Submitted
34	D4.3	Command and control unit	EVADS	EU_RES	30/06 /2020	30/06/2020	Submitted
35	D7.6	Business Model	EVERIS	Consortium Confidential	31/07/20 20	30/07/2020	Submitted
36	D6.7	Second Evaluation reports	CMRE	EU_RES	28/02 /2021	10/03/2021	Submitted
37	D1.2	Final Concept of Operation, Use Cases and Requirement s	HMOD	EU_RES	31/03 /2021	07/04/2021	Submitted
38	D5.5	Final Integrated ROBORDER System	EVADS	EU_RES	30/06 /2021	12/07/2021	Submitted
39	D6.9	Operator Training Manual	ORFK	EU_RES	30/06 /2021	12/07/2021	Submitted
40	D6.5	Final M&S based Test Bed Demonstratio n	CMRE	EU_RES	31/08 /2021	31/08/2021	Submitted
41	D6.8	Final Evaluation reports	CMRE	EU_RES	31/08 /2021	31/08/2021	Submitted
42	D7.5	Final Disseminatio n reports	HMOD	Public	31/08 /2021	31/08/2021	Submitted
43	D7.7	Report on Standards and Collaboration s	CMRE	Public	31/08 /2021	31/08/2021	Submitted

44	D7.8	Exploitation plan and sustainability model	EVERIS	Consortium Confidential	31/08 /2021	31/08/2021	Submitted
45	D8.5	Final Activity report	CERTH	Public	31/08 /2021	31/08/2021	Submitted

Table 3 - Table of planned ROBORDER deliverables

Each one of the aforementioned deliverables is connected to a milestone that ensures the progress and accomplishment of the project's objectives. The list of milestones and status is displayed in Table 4.

No	Name	Description	Lead beneficiary	Due Date	Status
MS1	Project setup and platform development roadmap	MS1 marks the successful initiation of the project work and establishing of the project identity. It includes: (i) the initial project management and quality assurance plan, (ii) the initial dissemination plan and communication activities, (iii) the initial user Concept of Operation, use cases and requirements, (iv) the initial technological roadmap, (v) the evaluation Methodology using benchmarking, (vi) the initial Self-assessment and data management plan. Deliverables contributing to MS1: D1.1.1, D5.1, D6.1, D7.1, D7.2, D8.1, D8.2, D9.1, D9.2, D9.3	CERTH	31/10/2017	Achieved
MS2	Operational Prototype	MS2 stands for the accomplishment of the ROBORDER architecture's roadmap. It includes: i) the Communication architecture report, (ii) the Performance assessment of ROBORDER configurations, iii) the techniques for Event and Activity Detection and Recognition and Intrusion and illegal communications detection and iv) the technical requirements and operational architecture. Deliverables contributing to MS2: D2.1, D2.2, D3.1.1, D3.2.1, D5.2, D9.4, D9.5, D9.6, D9.7	CERTH	30/04/2018	Achieved
MS3	1st Prototype	MS3 stands for the completion of the first development cycle of the project. It includes the 1st version of the ROBORDER platform integrating: i) the UxVs tele-operation framework and interface and ii) the Visual analytics and decision support tools based on risk models and reasoning methods. It also includes i) the Action plan for PUC, ii) M&S based Test Bed Demonstration, iii) the first evaluation report, iv), the 2nd cycle of the Concept of Operation, Use Cases and Requirements v) the Market Analysis, ix) the second iteration of the	CERTH	31/10/2018	Achieved

		Dissemination Reports and xii) the Mid-term review and progress report. An independent Ethics Review will be realized in parallel with MS3 . Deliverables contributing to MS3: D1.1.2, D4.1.1, D4.2.1, D5.3.1, D6.2, D6.3.1, D6.4.1, D7.3, D7.4.1, D8.3			
MS4	2nd Prototype	MS4 stands for the completion of the second development cycle of the project. It includes the 2nd version of the ROBORDER platform: i) Final Sensors Implementations and ii) Adaptability solutions for robotic platforms. It will also include i) Self-assessment and data management plan v2, ii) the M&S based Test Bed Demonstration and iii) the 2nd version of the self-assessment and data management plan. Deliverables contributing to MS4: D2.3, D2.4, D5.4, D6.4, D8.4	CERTH	28/02/2020	Achieved
MS5	Final System	MS5 marks the successful completion of the third SW development cycle. It includes: i) the M&S based Test Bed Demonstration, ii) the report on final end-user evaluation, iii) the Operator Training, (iv) the Report on Standards and Collaborations, v) the Dissemination Reports and vi) the Exploitation plan and sustainability model Public final activity report, vii) the second evaluation report and viii) Business model In addition, it will include i) the third cycle of the Concept of Operation, Use Cases and Requirements, ii) Event and Activity Detection and Recognition, iii) Intrusion and illegal communications detection, v) UxVs tele-operation framework and interface, vi) Visual analytics and decision support tools based on risk models and reasoning methods and vii) Command and control Unit. Deliverables contributing to MS5: D1.2, D3.1, D3.2, D4.1, D4.2, D4.3, D5.5, D6.5, D6.7, D6.8, D6.9, D7.5, D7.6, D7.7, D7.8, D8.5	CERTH	31/08/2021	Achieved

Table 4 - Table of ROBORDER milestones

In order to keep track of the possible risks that the project might face in its duration and prepare the necessary mitigation plan, ROBORDER had a risk inventory per Work Package, where a brief description of the risks that could be identified, a likelihood, the impact that the risks were going to have and mitigation actions that could be used as responses were presented. The tables below contain only the risks that have been reported and were relevant until the end of the project.

No	Description	Likelihood	Impact	Response
1	New legislation on RPAS	High	Medium	Trial plans were prepared according to

	coming on force on 1st of July 2020.			the new rules.
2	User requirements and developed technology misalignment.	Low	High	User Requirements have been vetted, refined and prioritized in collaboration with the Technical Partners on several occasions during development.
3	Force Majeure on some end-user involvement	High	Medium	Partner PSNI requested to suspend part of their involvement due to the pandemic at the end of the period. The mitigation of such decision was considered in the recovery plan.

Table 5 - Risks identified in WP1

No	Description	Likelihood	Impact	Response
1	Autonomous waypoint-based navigation is not safe in the actual border conditions.	Low	Low	UGV can be driven manually while keeping interaction with the ROBORDER platform as if navigation was completely autonomous.
2	TEKEVER Contribution for the RF-Sensor prototype (T2.3) is cancelled	High	High	Restructuring of the work share between ELTM and EVADS. Risk was under control
3	Delay in the integration of the PRN system in the Port of Livorno	Low	Medium	Deployment of the PRN in a reduced configuration with less TX/RX antenna elements; postponement of the integration tests among AdSP-MTS, CNIT and FHR; postponement of the PUC 1.6 demo.
4	Integration issues with the hardware sensors appear.	Low	High	An assessment of the integration capabilities of the UxVs has been made in advance.

Table 6 - Risks identified in WP2

No	Description	Likelihood	Impact	Response
1	Deviation of model's performance due to different aspects of SAR and RGB imagery	Medium	High	It is crucial to collect data from both spectral domains. Efforts were also made to create a robust detector capable to operate efficiently in both domains by fine-tuning the detection model according to the characteristics of each spectral domain.
2	The proposed target tracking strategy may prove to be inefficient in case of highly maneuvering targets.	Medium	Medium	The tracking strategy was refined by considering also different motion models, e.g., the interacting multiple model (IMM).
3	The cyber-attack detection service has not be trained properly due to a small amount of trained data	Medium	Medium	The consortium will execute the foreseen scenario using real communication jamming equipment in order to collect sufficient data to accomplish the required classification.
4	TEK-EVER Contribution for unauthorized communications detector is cancelled	High	High	Restructuring of the work share between ELTM and EVADS. Risk was under control.

Table 7 - Risks identified in WP3

No	Description	Likelihood	Impact	Response
1	Operators are not familiar in AR/VR technologies	High	Medium	Appropriate training courses have been developed as well as comprehensive guidelines
2	Mission editor tool is not	High	Medium	Training courses have been

	sufficiently comprehensive for the operators			established in WP6 based on which potential operators will become familiar with the tool
3	Due to some technical limitations, in specific operational modes, ARTC module cannot be executed properly for given ROIs	Low	Low	Warning message for the specific problem.
4	Insufficient data amount for the risk models	Low	Low	A risk assessment was performed
5	Instability issues with the Dashboard	High	High	Stressing tests were performed to identify and correct the issues
6	Insufficient data for VR representation	High	Low	Due to the postponement of the trials, the consortium faced some delays in collecting the required data under real conditions. The amount of data that were collected during the exeution of the trials is considered sufficient to validate the performance.
7	Large map files	High	Low	The service has been integrated following a different approach requiring the availability of offline maps. The a priori knowledge of the operational area limited the surveyed territory and thus, the size of the corresponding map files.
8	Inappropriate displaying format and overflow of alert messages	Low	Low	A proper filtering mechanism has been developed to avoid any message overflow as well as the indications of the end-user were seriously considered to present comprehensively the detection outcomes
9	Some functionalities of the Dashboard need to be updated after integration issues might appear	High	Low	The Dashboard was constantly evaluated during rehearsals prior to each PUC evaluation and if any modifications were needed they were handled prior to the demonstration

Table 8 - Risks identified in WP4

No	Description	Likelihood	Impact	Response
1	Central server storage capacity and efficiency	Medium	High	As a mitigation, a study of the necessary computational requirements was performed and the addition of complementary hardware was assessed.
2	Security of communications between the ROBORDER system is breached	Low	High	As a mitigation, a communications schema without the use of internet has been designed (which was also reflected in the final architecture) eliminating any possibility for any external inference.
3	Unbearable latency of the track outputs available at the ROBORDER dashboard (e.g., greater than 20s)	Medium	Medium	Possible countermeasures that were suggested: 1) further optimization of the processing strategy, 2) truncate the available data to decrease the data amount for processing 3) updates on latest versions for the software components.
4	Software integration delays	High	High	A secure VPN in EVADS premises was

	due to the Covid-19 situation			in place for everis to access the physical server in case it was necessary to integrate and test new SW modules
5	The elevation profile of the terrain blocks the line of sight of the LRW communications between the server and the UxVs	Low	High	The system was correctly tested in the exact same environment during the pre-executed scenarios

Table 9 - Risks identified in WP5

No	Description	Likelihood	Impact	Response
1	Measures to fight COVID-19 outbreak will impede the organization of Bulgarian demonstration, since partners will not be allowed to travel	Low	High	Assessed restrictions to travel across Europe for all the partners. The live demon was postponed live demo to a reasonably safe time and was organized later with limited participation.
2	ROBORDER components not ready to perform the demonstration	Low	High	Adapt the integration tests to mimic the PUC scenarios; Perform additional integration tests using standalone services; Validated their functionalities using simulated data
3	There will be no appropriate place for the UAVs to take-off and land.	Low	High	The execution of the trials must involve the use of proper aviation infrastructure. If this not possible, the responsible partner progressed with the construction of an appropriate “airstrip” as it has been done in the Bulgarian demonstration
4	Input from prototype development will not provide material for training content related to the user interface training.	Medium	Medium	Cooperation started with WP5 partners getting continuous input as integration proceeds. Training content was aligned.
5	Proper equipment for communication jamming is not available	High	High	The consortium and more specific the demonstrator organizer will investigate all connections within their network to provide the required equipment
6	External participants will be involved in demonstrations so essential technical details will be presented	High	High	The external attendees could participate only after a signed NDA will be established between the external party and the project’s coordinator
7	No demonstration/real operational scenario has been performed	High	High	Due to the covid-19 pandemic, the foreseen demonstration has been postponed drifting the final end-user requirements submission. An updated plan was compiled and followed with the limited participation of the absolutely necessary partners for the physical execution of the demonstrations implementing the mitigation plan that has been indicated by the reviewers. Currently, the consortium managed to successful execute all the foreseen trials eliminating this risk.

Table 10 - Risks identified in WP6

No	Description	Likelihood	Impact	Response
1	Overestimation or underestimation of existing prices in the market of ROBORDER competitors	High/Medium	High	While creating ROBORDER business model to accurately estimate the savings of possible ROBORDER deployment and in financial plans we carefully assessed the pricing of the system
2	Lack of relevant and important data due to the EUCI information included in the deliverables about the project results, system operation and suitability for the market	High	High	Request of responsible partners for the needed information, which was available in classified deliverables, identified the data, which was non-classified, or which could be declassified for the purpose of exploitation and sustainability analysis and planning.
3	Limited understanding of the market potential and trends due to the nature of the market (end-users are LEAs and information is restricted)	High	Medium	Continuous communication for input and insight from LEAs and project's technical partners.
4	Inadequate information and false image creation about the project in the media and in the market	High	High	Carefully assessed the information, which was shared with the outside of the project consortium, evaluated the clarity of the messages shared and ensured substantial communication and dissemination from the project partners.
5	Difficulty in commercialization, exploitation and sustainability of the project results due to the Risks 1, 2 and 3.	High	High	Continuous targeted communication to the relevant stakeholders and continuous showcasing of ROBORDER in the relevant market fairs and exhibitions.
6	Outbreak of COVID-19	Low	High	The outbreak of COVID-19 has seriously hampered the organisation and participation during the last months of this reporting period. To continue with the dissemination of the project, ROBORDER has created the "Network of Interest" group, in order to reach out to stakeholders and keep them engage for the upcoming activities (such as demonstrations and evaluations). The consortium focuses on participating in remotely performed dissemination activities

Table 11 - Risks identified in WP7

No	Description	Likelihood	Impact	Response
1	Partner drops out of the project	Medium	Medium	A direct replacement was sought after. Similar expertise were the focal point of the replacement and the good reputation of the consortium I facilitated all partners in this task.
2	Brexit and UK partners	Low	Low	UK partners, CENTRIC and PSNI, have acquired all necessary authorizations in order to have full access to the EC portal and EU

				information.
3	Delays in contribution by partners	High	Medium	All partners were provided in advance with detailed timeplans regarding all respective tasks in order to agree upon before proceeding with its execution. In this manner, the coordinator kept better track of the expected deliverables and outcomes and the partners had enough time to plan in advance.
4	Failure to provide results according to the project's objectives	Medium	High	All respective WP leaders had weekly-biweekly telcos among involved partners in order to keep a recurring communication and to overview the progress of the tasks towards the project's objectives.
5	Delay in payments	Low	Medium	Due to covid lockdowns and limited access to premises, some delays were noticed in terms of payments. All partners were dully informed about the progress of each payment in advance.
6	COVID-19 implications	High	High	COVID-19 crisis altered the initial plan of demonstrations and pilots. New scheduling was needed, after close observation of the pandemic conditions that postponed the execution of the demonstrations for a period of time. Remote participation and meetings of the consortium were held to keep the project on track.

Table 12 - Risks identified in WP8

No	Description	Likelihood	Impact	Response
1	Legislative differences among EU member states may prevent the use of ROBORDER's platform	Medium	High	The responsible partners for the execution of the demos have investigated the legislation in their countries in order to ensure the successful organisation of the demonstrations. These partners provided insight and guidelines to the rest of the consortium in order to assist them in investigating such issues in all EU member states that are involved in the project.
2	Ethics concerns regarding the surveillance aspect of the project	Medium	Medium	The consortium has made sure to update their ethics requirements by taking into serious consideration the ethics aspect of the surveillance that is offering. Information sheets are provided to data subjects in order to properly inform them about ROBORDER's activities, special measures were adopted in order to inform non-involved people about ROBORDER's activities, a Data Protection Impact Assessment has been conducted.
3	Ethics concerns regarding ROBORDER's actions in borders during a migratory crisis	Medium	Medium	The consortium was as transparent as possible regarding its activities in the border of the EU, as all partners fully understood that some of the platforms'

				actions might be misinterpreted by some social groups. Proper communication towards any concerned group of people was of great importance and of high priority.
4	Participation of employees	High	Low	As the fair majority of the participants were people that were directly involved in the consortium or other people that were employed by ROBORDER's beneficiaries, it was highlighted in the information sheet and during the Q&A session that was held prior to the demo that there was no better or worse treatment to the employees that wanted or not to participate, respectively. All participants felt free to decide whether they would like to participate or not without having to consider positive or negative consequences.

Table 13 - Risks identified in WP9

In the sub-sections below, each WP is analysed separately with a table containing: 1) the objectives of the WP, along with the involvement of the objective to a certain task and milestone. 2) The evaluation strategy of each objective in order to assess the quality and progress of every task and 3) lastly the success indicators.

3.1 WP1: User requirements and pilot use cases

WP1 is representative and indicative of the system's operational needs and as such, it has produced a significant amount of material that served as the basis for the entire project. In order to meet the multidimensional challenges and the strategic objectives, the efforts of all relevant stakeholders were directed towards covering a wide range of issues. Using practically tested methodologies, the End Users defined a well-established CONOPS along with a comprehensive set of Use Cases that serve as the testbed for an extensive set of high-level requirements and technical specifications. Last but not least, the project was examined through a legal and ethical lens to ensure compliance with EU ideals and regulations.

WP	1		
WP Leader	HMOD		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Analysis of user requirements and operational aspects** This task will focus on the extraction of user requirements from the use case scenarios.	T1.1.	MS1-MS4 (End month:M36)
2	**Analysis of security requirements** This task will focus on the security requirements in relation to the technology systems in use and the integration of the solution.	T1.2	MS1- MS4 (End month:M36)
3	**Analysis of ethical and legal requirements** This task will consider the ethical and legal requirements both for the developed system and for the ongoing compliance of the project.	T1.3	MS1- MS4 (End month:M36)
4	**Design of the pilot use cases** In the context of this task, the requirements collected from the users at T1.1 will be the basis for the development of the	T1.4	MS1- MS4 (End month:M36)

	required set of real use case scenarios.		
5	**Design of concept of operations** In this task, general ROBORDER concept of operations for surveillance missions with a swarm of or standalone heterogenous robots will be defined.	T1.5	MS1- MS4 (End month:M36)

WP Evaluation Strategy	
A/A	**Evaluation strategy description**
1	The evaluation strategy of the user requirements has been defined to include a qualitative evaluation step in the process: ⇒ Building upon the first results evaluation, the requirement specifications will be adjusted both according the evaluation findings and also on recent market developments. All project participants will assess the definitions which will be also adjusted based on the qualitative evaluation.
2	The evaluation strategy of the security requirements involves: ⇒ Collaboration between end-user and technical partners in order to identify hardware/software security issues and to protect the generated information within the ROBORDER solution ⇒ Monitor every information through the project's SAB in order to be compliant with the security regulations.
3	The evaluation strategy of the ethical and legal requirements will involve: ⇒ Compliance with the project's DMP and the established Data Protection Rules. ⇒ Alignment with the outcomes of the Ethics Requirements Work Package. ⇒ Collaboration between technology and end-users on legal and ethical frameworks
4	The evaluation strategy of the pilot use case design involves: ⇒ Detailing the scenarios ⇒ Collaboration between the end-users and the technical partners on deployment of ICT solutions ⇒ Finalizing use cases for inclusion in the testing strategy ⇒ Final review of testing strategy and use cases with technical and research partners ahead of operational testing. All the consortium will collaborate to assess the developed testing strategy before the operational testing phase.
5	The evaluation strategy of CONOPS involves: ⇒ Define the role of human operator and co-operators with other stakeholders. ⇒ Identify the needs for training the operators.

WP Indicators		
A/A	**Highest expectation**	**Lowest expectation**
1	Project goals and scope fully achieved	80% of the project goals and scope satisfactorily achieved
2	Project goals and scope fully achieved	80% of the project goals and scope satisfactorily achieved
3	Project goals and scope fully achieved	80% of the project goals and scope satisfactorily achieved
4	Accuracy, reliability and concise descriptions of the developed use cases. Project goals and scope fully achieved.	80% of the project goals and scope satisfactorily achieved
5	Effective and efficient inspection progress and situation awareness. Project goals and scope fully achieved (increase mission effectiveness by 5% and reduce to 0% the reported errors).	80% of the project goals and scope satisfactorily achieved

Table 14: WP1 objectives, evaluation strategy and indicators

3.1.1 Final Assessment

Objective 1: The End Users provided a preliminary set of User Requirements based on real-life scenarios drawn from actual experience from LEAs and border authorities and then proceeded to revise them based on the demo results, the Technical Partners input and the market developments for the duration of the project. As far as the End Users are concerned, the consortium arrived at a comprehensive set of User Requirements, hence the Project goals were met and its scope fully achieved.

Objective 2: An analysis of related security requirements applicable to the technology systems appropriate for use in ROBORDER solution has been made. Produced set of security requirements encompasses hardware and software security as well as the security and protection of generated information aspects within the ROBORDER solution. The elicited security requirements have been incorporated in ROBORDER solution and tested in different live tests and demonstration. The task is successfully concluded meeting all expectations according to GA without any deviations.

Objective 3: In T1.3, ORFK evaluated the ethical and legal requirements both for the developed system and for the ongoing compliance of the project. To facilitate project implementation, support documents and internal regulations were prepared and released such as Ethical Code and Project Security Procedures. A set of Data Protection Rules were drafted as input to the Data Management Plan. Moreover, the overall ethical and legal framework has been developed that provided a guidance with regard to the overall project.

ORFK ensured the continuous monitoring of the project from beginning to end, review of deliverables and operating the controlling mechanism, as well as preparing corresponding (ethical and legal compliance) parts of the periodic and final reports.

Objective 4: The End Users provided a comprehensive set of realistic Use Cases that encapsulate and test the User Requirements described in T1.1. The process involved the Technical Partners in order to ensure thoroughness and consistency. As far as the End Users are concerned, the designed Use Cases were representative of actual field use and allowed for thorough testing, hence the Project goals were met and its scope fully achieved.

Objective 5. Human operator and co-operator roles related to the different border surveillance use cases are defined and presented in the D1.1 and D1.2 deliverables. The Concept of Operations diagrams developed and reported during the project presents the relationships between Human operators, Operating environment, Autonomous system, and other stakeholders. Operator roles, information sharing needs and characteristics were also defined in end-user interviews for different use cases. The relationships with other work packages and with the ROBORDER system, including architecture, user interface and hardware elements, were also considered during the ConOps work. The final Concept of Operation diagram presented in the D1.2 indicates on how the human operator is connected with and affected by the operating environment, ROBORDER Command & Control User Interfaces, Autonomous system, Use Cases and Other stakeholders. The D1.2 also lists main operator tasks and requirements for operator work, which can help to plan operator training and skill development. Use of new technologies included in the ROBORDER system is quite demanding and requires additional familiarisation and training.

3.2 WP2: Sensing, robotics and communication technologies

The aim of WP2 was to establish innovative technologies and building blocks that empower the ROBORDER platform in terms of sensors, carriers/platforms and communication solutions. The goal was successfully reached. Several systems addressing heterogeneous technologies have been designed, prototyped and tested under laboratory and real world conditions.

WP	2		
WP Leader	Elettronica		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Cloudlet based communications** This task aims at identifying the communication link that is	T2.1	MS2-MS4 (End

	required to interconnect all the deployed UxVs. (TRL6-TRL8)		month:12)
2	**Passive radar on board UAVs and USVs** This task defines the passive radar operation mode as well as the hardware optimization according to the ground radar network (TRL3).	T2.2	MS2-MS4 (End month:33)
3	**RF signal sensor on board UxVs** The task aims at developing a Radio-Frequency Communications sensor for monitoring mission-specific communications (TRL14).	T2.3	MS2-MS4 (End month:33)
4	**Sensor adaptability** This task will design and develop the SIMROB simulation environment (TRL1).	T2.4	MS2-MS4 (End month:33)
5	**Re-configuration of agents and carrier solution** The task includes activities that will modify the sensors and the assets in order to operate in adverse weather conditions. In addition, a carrier solution is developed to operate the UGVs as re-charging stations for small UAVs (TRL2).	T2.5	MS2-MS4 (End month:33)
6	**Photonics based radars** In this task, the development and characterization of the photonics-based radar system and optical clock will be carried out (TRL4, TRL5).	T2.6	MS2-MS4 (End month:33)

WP Evaluation Strategy

A/A	Evaluation strategy description
1	⇒ Data transmission rate ⇒ Delays between data acquisition and availability at the highest development level ⇒ Connection stability
2	For the passive radar evaluation strategy, the following strategy is established: ⇒ Compact construction ⇒ Quantitative evaluation of the detection accuracy ⇒ Quantitative evaluation compared to the ground-based radar
3	The evaluation strategy for the developments of this sensors will focus on: ⇒ Physical dimensions & Weight of the sensor ⇒ Number of channels for the direction finding ⇒ Detection range
4	The evaluation strategy of the sensor adaptability involves: ⇒ Use case and assets coverage ⇒ Computation time
5	The evaluation strategy of this task involves: ⇒ Proper KPIs according to specific IEC standards ⇒ KPIs for the carrier solution
6	⇒ Number of RF carriers ⇒ Noise suppression ⇒ Maximum range ⇒ Range resolution

WP Indicators

A/A	Highest expectation	Lowest expectation
1	⇒ Adequate data rate according to the end-user requirements ⇒ Instantly information of the operator when the event is performed ⇒ Data package loss is kept at minimum levels.	⇒ Insufficient data rate leading to low levels of situational awareness ⇒ Delays between the actual event and the information nonetheless; within an acceptable timeframe ⇒ Good assessment of the module's performance by the evaluators.
2	⇒ Receiver size: Each dimension below 1m, Weight: <20 kg ⇒ Max detection range compared to the coastal radar: improvement >20% ⇒ Covered area: improvement >50%	⇒ Increased receiver size: Inappropriate for integration on UxV ⇒ Max detection range compared to the coastal radar: improvement 5% ⇒ Covered area: improvement >10%

3	⇒ Volume: 300x40mm, Weight: ≤1 kg ⇒ Number of channels: 6 ⇒ Detection range ≥1km (sea installation), ≥2km (air installation)	⇒ Volume: >300x40mm, Weight: ≥1 kg ⇒ Number of channels: 2 ⇒ Detection range: <1km
4	⇒ Use case and assets coverage: 100% ⇒ Computation time: 1/20 of the mission time	⇒ Use case and assets coverage: 60% ⇒ Computation time: Over 1/20 of the mission time
5	⇒ Resistance reaching the standards of IP67 for UGVs and IP68 for small UAVs ⇒ KPIs for the carrier solution: (i) Fully re-charge the UAV, (ii) TOL operations (iii) Autonomy of 3 hours flight and/or 2 re-charge cycles.	⇒ Applied standards compliant with IP65 ⇒ KPIs for the carrier solution: (i) Not fully recharge, (ii) non TOL operations, and (iii) 1 re-charging cycles.
6	⇒ RF carriers: Extension to 3 (S, C and X band) ⇒ Signal-to-Noise: at the state-of-the-art > 80db/1MHz ⇒ Maximum range: 30km ⇒ Range resolution: Improved < 1m	⇒ RF carriers: Single band operations ⇒ Signal-to-Noise: at the state-of-the-art > 60db ⇒ Maximum range: 7.5km ⇒ Range resolution: 1.5 m

Table 15: WP2 objectives, evaluation strategy and indicators

3.2.1 Final Assessment

Objective 1: The initial plan regarding the communications links was to deploy a secure VPN over a cloud network. The latter would be utilized as an intermediate node of a unified network where all UxVs would transmit the received data through their GCSs to the cloud infrastructure and finally to the ROBORDER framework. After the first assessment of the end-user requirements, this architecture was abandoned as in distant border areas, the signal coverage would not be sufficient to meet the requirements. Thus, the objective for the cloudlet communications is not valid as this approach was not followed considering also that the updated version of the architecture.

Objective 2: Several passive bistatic radar sensors are available on the market for military purposes. These systems rely on broadcast illuminators of opportunity such as FM radio or digital terrestrial television and they are ground based and stationary. In the framework of ROBORDER, the Fraunhofer FHR has researched, designed and developed the PR from existing and new hardware components. The system was modified and adapted to operate at X-band frequency, which is illuminated by the PRN. The signal processing scheme of the data was also developed using GNU Radio, which is a free open-source software development toolkit and capable of real time signal processing. The PR development started its initial stages of research and design in the lab which is TRL 4. The evaluation relied on quantitative metrics based on detection performance and tracking of targets. The quantitation varies with of course target sizes, composed material of targets and background interference (clutter and noise). For specific scenario, the various simulation of the system perform were implemented and reported in Deliverable D2.3 and D5.5. However, though out trials and testing of the PR, the system was able to detect car and small drone in real radar operation. To deliver the TRL 7 service, the system will be demonstrated in real time and integrated with the overall ROBORDER system. Although the real time demonstration is not yet implemented, data from a previous trial was tested with the overall ROBORDER system. The real time demonstration is expected in July 2021 together with the PRN and assures that the TRL 7 service is met. The operation of the PR on a flying platform will not be conducted as the location of the demonstration is on the flight path of the Pisa airport. With all the activities implemented, product development and demonstrations, all requirements are achieved to the highest quality and expectations.

Objective 3: The objective "developing a Radio-Frequency Communications sensor for monitoring mission-specific communications " has been reached. The evaluation of the RF-sensor can be summarised as follows:

- Physical dimensions & Weight of the sensor: The prototype build in ROBORDER framework has a dimension < $0.5m^3$ and weight < 10kg. It can be easily integrated in UGVs and UAVs with corresponding payload.
- Number of channels for the direction finding: the system uses a circular array and scanned the 2D space 360°/180°
- Detection range: up to 2km

Although the system was firstly planned to be integrated in an UAV of TEKEVER, in the end, in coordination with the Consortium, the RF sensor has been built to fit on a UGV.

Objective 4: The objective "design and develop the SIMROB simulation environment "has been reached. The evaluation of SIMROB can be summarised as follows:

- All agreed Use cases have been implemented
- Computation time → adjustable up to near real time

Objective 5 was aimed to provide vehicles which sustained different levels of protection against the ingress water, dust and other small particles. This protection is typically specified by the Ingress Protection standard, which is composed by two numbers specifying the protection against solid particles and liquids. IP6X means no ingress of dust, whereas IPX7 means protection against immersion in water up to 1 meter and IPX8 of more than 1 meter. The final UGV selected for the Roborder project was based on a general-purpose all-terrain electric car, for which IP ratings are usually not rated, however it has a protection equivalent to IP54 (ingress of dust does not interfere with normal operation, protection against splashing of water). Sensors and actuators for UGV were selected with a minimum IP65, and those without enough protection were mounted inside IP67 cabinets, which Peltier-based based IP67 cooling systems. No laboratory testings were done, however all equipment was installed following the manufacturer instructions for mounting and sealing. The other goal of Objective 5 was to provide a system for deploying and charging small UAVs by UGVs. Attachment of UAV to UGV was tested in a laboratory environment, where a mock UAV was suspended and attached to the UGV. After this the mock UAV was loaded with an equivalent mass to the actual mass of the UAV used in the project and the UGV was moved through uneven terrain, stepping over curbs, taking turns and sudden brakes and the mock UAV remained attached to the UGV. Recharging was tested in a laboratory environment with a battery at 10 amperes.

Objective 6: The photonics-based radar network has been successfully designed, developed and deployed at the port of Livorno. The specific operational test (PUC 1.6) has confirmed the achievement of all the technical KPIs, thus meeting the expectations. The time scheduling for this activity has shown a consistent deviation, as demonstrated by the fact that the photonic radar network has been completed only in July 2021, just before the operational test. Moreover, one out of three radar heads could not be deployed before the test.

3.3 WP3: Detection and identification of border-related threats

The scope of this WP was to develop the software modules for the detection and identification of all the identified border-related threats. The activities have been carried out in accordance with the expectations, with no reported deviations.

WP	3		
WP Leader	CNIT		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Detection of pollution incidents** An oil spill detector based on either visual or SAR images will be delivered in the context of this task (TRL9).	T3.1	MS2, MS5 (End month:35)

2	**Identification and tracking of illegal activities** This task will develop the appropriate radar-based detection schemes for identifying metallic objects of interests in the open sea. In addition, the task involves the development of visual detection algorithms as well as activity recognition scheme for specific objects (TRL9-TRL11).	T3.2	MS2, MS5 (End month:35)
3	**Low level of fusion data** This task involves the development of a multi-sensor fusion approach aiming at increasing the detection capacities (TRL12).	T3.3	MS2, MS5 (End month:35)
4	**Detection and classification of cyber and cyber-physical attacks** This task will deliver an intrusion detection and classification module to identify potential cyber-attacks (TRL13).	T3.4	MS2, MS5 (End month:38)
5	**Identification of unauthorised communications using RF sensor** This task will deliver a set of algorithms for the identification of unauthorised communications based on the RF readings (TRL14).	T3.5	MS2, MS5 (End month:38)

WP Evaluation Strategy

A/A	Evaluation strategy description
1	⇒ Quantitative evaluation of the performance (accuracy, false positive events etc.) ⇒ Computational cost ⇒ Detection latency
2	The evaluation strategy for the identification of illegal activities involves will focus on: ⇒ Detection accuracy (precision, false positive rate, true positive rate, area under curve) ⇒ Processing time: Resulted FPS, latency
3	⇒ Improvement of the detection accuracy ⇒ Time efficiency
4	The module for the classification of cyber-physical attacks will be evaluated through the following strategy: ⇒ Classification metrics ⇒ Time efficiency
5	The evaluation of the RF-based detection schemes will focus on: ⇒ Detection performance (precision and detection latency) ⇒ Physical dimensions and technical specifications (for on-board integration)

WP Indicators

A/A	Highest expectation	Lowest expectation
1	⇒ Recognition accuracy: ~5% improvement ⇒ False positive events: ~10^{-6} ⇒ Resulted frame rate: ~ 8 fps	⇒ Accuracy: SoA performance ⇒ False positive events: ~10^{-3} ⇒ Resulted frame rate: ~2 fps
2	⇒ Detection accuracy: ~5% improvement ⇒ Detection probability: ≥ 80% ⇒ Frame rate: ~7 fps	⇒ Detection accuracy: SoA performance ⇒ Detection probability: < 80% ⇒ Frame rate: ~ 2 fps
3	⇒ Performance: Near real-time ⇒ Detection improvement: ~5%	⇒ Performance: High latency ⇒ Detection improvement: ~0%
4	⇒ Accuracy: ~5% improvement over the baseline ⇒ Latency: Real time	⇒ Accuracy: SoA performance ⇒ Latency: 1 sec
	⇒ Accuracy: ≥ 90% ⇒ Dimensions: Proper for onboard integration	⇒ Accuracy: <80% ⇒ Dimensions: Increased weight and size.

Table 16: WP3 objectives, evaluation strategy and indicators

3.3.1 Final Assessment

Objective 1: Initially, the service was designed and evaluated under laboratory conditions using a custom-built SAR-based image dataset (TRL5). The evaluation relied on quantitative metrics such as mean Intersection-over-Union (mIoU) as commonly adopted in semantic segmentation approaches. Since related SoA methods were validated on different datasets, the comparison of the deployed module to SoA techniques is not straight-forward. Yet, apart from its sufficient results, the novelty of the developed model relies on the semantic segmentation approach which eventually could result to an estimation of the disaster incorporating though, additional sensor parameters. Instead of labeling the entire processed image, the module can accurately annotate instances of oil spills and other relevant classes and thus, extract crucial informative content. The overall performance of the service is considered sufficient in terms of accuracy metrics and processing time (reported in D3.1 "Event and Activity Detection and Recognition" [RESTREINT UE/EU RESTRICTED]). To deliver a TRL 7 service, the model was upgraded to a service integrated to the overall system following the final version of the architecture and was evaluated in a real case scenario under the 1st demonstration. However, due to environmental safety restrictions, the evaluation was performed over simulated oil slicks created with rhodamine as similarly was used in other H2020 projects. As rhodamine's spectral characteristics differ from an actual oil spill, an RGB sensor was utilized for the detection process. Thus, the detection model was efficiently modified for processing visual data also. During the operational evaluation, quantitative metrics were also calculated, such as true positive and false positive events which were reported and analysed in D6.7 "Second Evaluation reports".

Objective 2: Concerning the detection and tracking by the photonic radar network, a novel specific module has been implemented. First, a multi-sensor multi-target tracking (MS-MTT) processing strategy has been identified. This strategy has been then optimized, with the capability of running both a non-coherent analysis (i.e., discharging the information included in the phase of the radar signals) or a coherent analysis (considering the signal phase to reach a hyper-fine resolution). The module has been successfully used in the operational test related to PUC1.6, allowing to extrapolate quantitative metrics. Concerning the visual object detection, initially, the training of the selected model relied on a dedicated dataset in order to fulfil the end-user requirements. After various evaluations on the corresponding set and adaptations of the training set, we concluded into a versatile dataset that meets the project's requirements. At a second phase an efficient SoA tracker was incorporated to complement the framework with tracking abilities and at the same time improve the efficiency of the module. The overall performance by incorporating the tracker almost doubled the processing fps. In addition, all objects were successfully tracked achieving the foreseen tracking accuracy in which they were present while removing deep learning detection artefacts from the input, reducing the chance of a false positive object in detections. Additionally, various modifications have been considered in order to adapt to the various requirements of the project and also improve the performance of the service. The final version of the detection module has been delivered and reported in D3.1 "Event and Activity Detection and Recognition" [RESTREINT UE/EU RESTRICTED]. In terms of integration, the detection outcomes have been successfully consumed by higher-level integrated components. To deliver a TRL7 service by demonstrating it in operational environments, the model has been fully integrated as a service into the various versions of the prototype and thoroughly evaluated in two demonstrations, the 2nd and the 3rd trial. The deployed module focused on activity detection, using techniques from the tracked objects that appear in the footages, with focus points to evaluate processing performance and the operational performance. For processing performance, there were several possible areas where latency could degrade execution but mainly slow frame processing from the deep learning input and the internal frame processing queue. However in both cases, in the real scenario, the input fps was adequate to real-life video with a low stutter with the frame queue latency monitoring tool never reaching over the 2-second latency alert threshold, which measured the time between an input being received and the time of processing the frame. However, this scenario did not test the limits of the processing queue, so to cover expectation, an artificial stress test was run which operated smoothly beyond 100+ fps before impractical conditions were met beyond expectation and any real-world scenario. However, this did not scale as well when a high number of objects were also being tested across multiple visual input streams due to the computational time complexity gradient. As for the visual object tracking, all objects were successfully tracked beyond 90% accuracy across frames in which they were present while removing deep learning detection artefacts from the input, reducing the chance of a false positive object in detections. In terms of event detection, an alert was able to be raised to the approximate area of the activity in the scenarios. Conversely, the absolute minimum and maximum thresholds were not tested due to the limited set of scenarios, so ideally more scenarios would need to be run to get an accurate result value. A qualitative evaluation would seem more fitting due to the novelty of the metrics produced, yet limited estimates lead to 75% plus leading to some level of activity detection output.

Objective 3: The initially developed solution of image data fusion reported in D3.1 "Event and Activity Detection and Recognition" [RESTREINT UE/EU RESTRICTED] has been validated under laboratory conditions to reach a TRL4. Nonetheless, due to hardware restrictions and modifications on the architecture, a different approach was adopted in order to provide an approach for more accurate detections. The updated model focused on combining sensory streams from different sources to estimate more accurately the exact location of the asset that performed the detection. To this end, the developed fusion scheme has been evaluated and validated through a representation containing the path defined by the mission planning nodule, the path followed by the UAV (actual path) and the predicted path by the fusion scheme. In addition, the process was performed through data collected by several different missions while the validation approach was adopted due to the way paths are produced by the mission planning module. Specifically, each path is produced using waypoint, with a straight line connecting two waypoints. Since no relevant information for the path coordinates between the two waypoints is available and at the same time the telemetry data are transmitted asynchronously by the UAV, the most appropriate approach of performing the validation is through the visual representation of the aforementioned paths. The validation relied on real-collected data from previously executed missions which eventually were processed to deliver a TRL5 service.

Objective 4: Initially, the IDCM module and service was designed and evaluated under laboratory conditions using simulated telemetry data from the ROBORDER's autonomous agents (TRL5). The evaluation relied on metrics such as detection accuracy and latency that are commonly adopted in intrusion detection approaches. As reported in D3.2, the average detection and classification accuracy of the service was estimated approximately equal to 94% outperforming the SoA performance. A number of innovative aspects have been brought into the design of the IDCM module to achieve this result, including the following:

- Smart model training: IDCM can automate the full cycle of training and testing, where for each set of data different models are being trained and based on their performance the best matching model is being chosen automatically. There are several factors in choosing the best model such as demanding computation resources, false-positive rate, etc.
- Detection of the root of the anomaly: Unlike many other intrusion detection solutions that are unable to identify the root of the anomaly, IDCM can detect the root of the anomaly in an automated procedure and classify the types of the attacks.
- Compatibility with noisy sensory data: IDCM is not only capable of detecting anomalies by feeding clean data for training, but it also capable of pre-processing noisy sensory data to minimize the false positive rate.
- Detection of zero-knowledge attacks using unsupervised learning: IDCM is fully integrated into the realistic environment and its models can be trained even when the provided data is incomplete and unlabelled. Moreover, by using advanced deep leaning techniques, IDCM can detect attacks that have not been seen before and are still unknown to the research community.

To deliver a TRL 6 service, the module was upgraded to a service integrated to the overall system and was evaluated within the operational test PUC2.1 "Detecting Jamming Attacks" that was conducted during the 2nd demonstration. During the operational evaluation, detection accuracy metrics were calculated, including among others the true positive and false positive events which were reported and analysed in D6.8 "Final Evaluation reports".
Objective 5: This task aims to deliver a set of algorithms capable of detecting unauthorized communications based on the RF Sensor developed in T2.3. In order to achieve this goal, direction finding and clustering algorithms were developed in order to localize and classify all the RF signals that the sensor detects and determine whether or not they represent a threat. These detections have been integrated in the Command and Control Unit developed in T4.7. This module was evaluated initially with simulations, afterwards in a laboratory environment, recreating the conditions that could be expected on field and finally during the demonstration of Bulgaria, participating in the use case of detecting a small UAV. With the performance of this demonstration the TRL 7 was reached.

3.4 WP4: Command and control unit functionalities

The WP focuses on designing and developing frameworks that comprise part of the highest implementation layer. The main objective of all the WP's models is to incorporate a simple and intuitive framework for operating and commanding the Unmanned Assets with the minimum operator involvement as well as an efficient navigation module to introduce the synergetic nature between the assets. In addition, the activities also involve models that focus on increasing an operator's awareness concerning the occurring events as well as an intuitive alert production mechanism.

WP	4		
WP Leader	CERTH		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Advanced human-robot interface** The main objective of the task is to develop a novel interface enabling the operator to monitor mission of the swarm and have natural interaction with the control system (TRL15).	T4.1	MS3, MS5(End month:35)
2	**DSL-based mission specification** This task aims at designing a domain specific language for the mission specification of the robotic devices (TRL18).	T4.2	MS3, MS5(End month:35)
3	**Autonomous resource task coordination** Within this task, a swarm platform will be developed aiming at handling situations where a complex and dynamic interplay is involved (TRL17).	T4.3	MS3, MS5(End month:35)
4	**CISE-compliant common representation model and semantic reasoning** The task aims to define a set of modelling requirements, ontologies and schemes for the semantic representation of the multi-modal data collected by different sources (TRL19, TRL20).	T4.4	MS3, MS5(End month:38)
5	**Risk models** This task aims at establishing a framework for the integration of risk models within the ROBORDER platform (TRL21).	T4.5	MS3, MS5(End month:38)
6	**Visual analytics and decision support** This task will develop the visual analytics methods that will enable the operator to have a visual overview of the situation as well as the mechanisms to provide high-level decision support (TRL22, TRL23).	T4.6	MS3, MS5(End month:38)
7	**Command and Control Unit** Under this task, a novel command and control unit will be	T4.7	MS5 MS5(End

	deployed so that all services of the work package could be integrated into one single unit.		month:38)

WP Evaluation Strategy	
A/A	**Evaluation strategy description**
1	The advanced operator's interface will be evaluated following the below strategy: ⇒ Situation awareness ⇒ Error rate in mission control
2	The DSL-based mission specification will be evaluated as follows: ⇒ Expressiveness ⇒ Powerful
3	The resource controller will be evaluated as follows: ⇒ Use case coverage ⇒ Accurate path extraction
4	The CISE-based model and semantic reasoning will be evaluated the following strategy: ⇒ Consistency and structure ⇒ Relevant to project scope ⇒ Scalable reasoning
5	⇒ Consistency and structure ⇒ Relevant to project scope ⇒ Decision complexity and Prediction accuracy
6	⇒ Visual analytics: Speed rendering and end-user requirements coverage ⇒ Decision support: user satisfaction, response time

WP Indicators		
A/A	**Highest expectation**	**Lowest expectation**
1	⇒ 5% improvement on SoA human-robot interfaces ⇒ 5% decrease of the mission error rate	⇒ SoA values for situation awareness ⇒ SoA error rates
2	⇒ Accurate description of the mission	⇒ Partial satisfaction of the operators
3	⇒ 100% scenario coverage ⇒ 90% path accuracy	⇒ 50% scenario coverage ⇒ 60% path accuracy
4	The developed ontology should be consistent and aligned with the CISE model while quality checks should conclude with only minor (the pitfall does not represent a problem) or no pitfalls. Ontology should be able to respond to all competency queries in a set of sample questions, which will be representative of all queries. For the evaluation of the semantic reasoning, the expected maximal value for the F-score is 90%.	Ontology should be **consistent.** Encountered pitfalls could be **minor or important,** but not critical. Ontology should be able **to answer the important competency questions**. The expected minimal value for the evaluation of the semantic reasoning is 70% in terms of F-score values.
5	Similar highest expectation as for the Objective 4	Similar Lowest expectation as for the Objective 4
6	⇒ Visual analytics: Real-time execution and end-user requirement fulfilment by 90% ⇒ Decision support: 90% in terms of f-score	⇒ Visual analytics: Low rendering time and end-user requirement fulfilment by 60% ⇒ Decision support: Minimal f-score value equal to 70%

Table 17:WP4 objectives, evaluation strategy and indicators

3.4.1 Final Assessment

Objective 1, Advanced human-robot interface. The main objective of the task is to develop a novel interface enabling the operator to monitor mission of the swarm and have natural interaction with the control system. The service was designed and evaluated as the prototype system (TRL6), which was archived. The evaluation relied on user evaluations. Due to COVID-19 situation, end-user evaluation wasn't possible to do, and evaluation was done remotely during demonstration as expert evaluation. Also lab evaluation was done during human centred development (more details in D4.1 [RESTREINT UE/EU RESTRICTED]). Based on expert evaluation the advanced human-robot interface could full fill evaluation criteria in situation awareness and error rates.

Objective 2: The ROBORDER Mission Editor managed to abstract the complexity of mission specification for non-experts. In particular, a web-based tool was developed the form of a visual and a textual editor. The visual editor provides a user-friendly GUI for users with limited or no programming skills by allowing them to define and customise robotic missions by customising a set of characteristics (e.g., type of mission, waypoints to be followed by the vehicles, sensors to be activated). The textual editor is based on a domain-specific language that provides the terminology (e.g., constructs), the syntax and the semantics to represent a UxV mission. The two editors are synchronised to each other and can be used either separately or in parallel by the user. The overall progress of this activity is considered satisfactory without any deviations from the original plan.

Objective 3: Under this task has been developed a novel system able to create, manage and supervise autonomous missions with multiple vehicles. This system is consisted of two separate parts. A novel path planning platform is developed so as to generate paths for the multi-robot missions. In addition to that, a robust mission management system, which undertakes to manage and process simultaneously multiple missions is used, in order to provide the appropriate information to the corresponding assets and modules, at certain stages of the missions. The path planning methodology can cope with convex and very complex-shaped concave operational areas, that may include no-go-zones and obstacles inside them. In addition to that, the mission management system allows the operator of the platform to check the mission during both the generation and the execution stages and decide if it is needed to intervene in order to stop or replan a mission, based on the operational feedback (e.g., optical material, generated alerts, threats etc.). The combination of these two features makes this module able to correspond to complex and dynamic operational scenarios. This way, the expectations of the objective 3 were met and no deviations were faced.

Objective 4: The Roborder ontology heavily relies on the EUCISE-OWL ontology, which is the serialized version of the CISE data model into the OWL 2 language. The core data entities are maintained in the RDF version and the SKOS schema is adopted for maximized expressiveness and robustness. Evaluating the ontology, the ontology pitfall scanner's output, was zero critical pitfall, and the majority of the important pitfall, is missing domain or range in properties, which was designed by choice to keep it extendable and reusable. Additional metrics of the semantic model refer to its accuracy and conciseness, which prove the ontology to be of great value, consistent and accurate in semantically describing the detected events. In D4.2 "Visual analytics and decision support tools based on risk models and reasoning methods" [RESTREINT UE/EU RESTRICTED], a set of competency questions were defined that originated from the pilot use cases and the user requirements and covered a range of subjects including incidents, alerts and vehicles. The service was validated initially with simulated and previously collected data as part of the final prototype reaching a TRL6. The foreseen TRL value has been accomplished earlier than the timeplan while its final value, TRL7, has been achieved after the execution of the three demonstrations where the service was properly demonstrated in all three events.

Objective 5: ROBORDER Risk Models module achieved to implement the software infrastructure required for the easy integration of risk models. In particular, T4.5 established a framework for the integration of risk models related to border threats. The module adopted the Frontex CIRAM methodology for the representation of operational and tactical risks. The outcomes of the predictions are aligned and labelled using the CIRAM terminology. It is considered that the expectations for this module are met. No significant deviations are encountered from the original workplan. Currently, only pre-defined suggestions are provided by the module. As a future development, it is planned to involve automated recommendations based on a case-based reasoning or a reinforcement learning approach.

Objective 6: Originally the approach of the visual analytics objectives was focused on improving the situational awareness of the possible risks to the conducted operations within the ROBORDER system, formerly focusing on weather and environmental conditions and exposing decision-support information, as the system moved to an isolated offline system. The objectives moved towards complementing the feed of data provided from the decision support feed, by enhancing incoming decision data with the ability to analyze historical trends, with added filters to build relevance to the current mission context as well as future missions. This shift to using a larger historical dataset, focused attention towards a high performing interface to sort, filter, and refine data promptly. So, the end-user requirements of the visual analytics module shifted to useability, performance, and decision impact. The final module was completed to its conclusion by meeting the set requirements. With a strong useability focus, and in some cases going beyond, such as the careful use of a colour blind-friendly colour scheme for data visuals. The careful use of filtered data for performance along with high precision controls for data manipulation, resulted in displaying data to show worthy of impacting the planning of future missions, leading to high fulfilment of expectations. In addition, the Decision Support Module uses the semantically enriched information in order to improve the overall operational picture and the situational awareness of the operator. In a simplified description, it comprises an alert production mechanism aiming at containing comprehensive information for the operator about the various events of interest. Such events include detected objects and vehicles that may be present in abnormal hours inside possible location polygons that are considered of high risk. The service has been validated during the execution of the three demonstrations delivering a TRL7 module.
Objective 7: Efforts have been focused on the development and testing of the command and control unit (later called "*Dashboard*"). It consists of a desktop application that integrates the services provided by the rest of the modules of the different work packages (WP). Therefore, it represents the highest level of implementation and development within the *Roborder System*. All established requirements have been implemented through the development of software components both on the *front-end* and *back-end* sides. On the *back-end* side, all the interaction with the message broker takes place, establishing the protocols and developments necessary to produce and consume messages with the communication interfaces, which are common to the entire system. On the other hand, the *front-end* side includes all the components related to the Graphical User Interface (GUI); everything that the user sees and uses. At this point, it is very important that the interface implementation has all the interaction elements necessary for operational management. This service has been evaluated in the three demonstrations of the ROBORDER project, reaching TRL7.

3.5 WP5: Integration of ROBORDER platform for the remote assessment of border threats

WP5 aims at designing and implementing a technical architecture, based on the user requirements, capable of integrating both software and hardware systems that have been developed in the scope of Work Packages 2, 3 and 4. An effective coordination between the technical partners has been implemented in order to integrate all modules in the Final ROBORDER system.

WP	5		
WP Leader	EVADS		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Technical system requirements and architecture** The task involves the design of the technological roadmap for the development of the ROBORDER platform (TRL24).	T5.1	MS1-MS5 (End month:12)
2	**Software integration** The task aims at deploying all the software components and	T5.2	MS1-MS5 (End

	exposing them as web services (TRL24).		month:42)
3	**Hardware integration** The task aims at collecting all the hardware components designed in other work packages and unifying their operations towards upgrading the capabilities of the used UxVs (TRL24).	T5.3	MS1-MS5 (End month:42)
4	**ROBORDER system integration** In this task, technical requirements and architecture will be realized while hardware and software modalities will be delivered as an integrated system (TRL24).	T5.4	MS1-MS5 (End month:43)
5	**System deployment and maintenance in testing environment** The task deals with the deployment of the final framework in border authorities and LEAs environment following the integration plan.	T5.5	MS1-MS5 (End month:43)
WP Evaluation Strategy			
A/A	**Evaluation strategy description**		
1	The evaluation strategy of the technical requirements and resulting architecture is mainly qualitative, by reviewing the percentage of high level requirements that are met by the design, and the degree in which use case scenarios can be carried out as desired by the individual pilots.		
2	The evaluation strategy of the platform integration is mainly quantitative by testing the resulting capabilities based on the high-level technical requirements garnered by the partners. The performance of the back-end services selected and deployed should be in accordance with the platform needs.		
3	The evaluation strategy of the final deployed system will rely on the end-users' satisfaction by enumerating the percentage of the use case coverage. For this qualitative evaluation, proper KPIs were identified within the context of WP1 and WP6.		
WP Indicators			
A/A	**Highest expectation**	**Lowest expectation**	
	100% of high importance technical requirements met by the architecture	75% of high importance technical requirements met by the architecture	
	100% of high importance technical requirements met by the platform	75% of high importance technical requirements met by the platform	
	100% of designed test cases completed and technical requirements fulfilled	75% of designed test cases completed and technical requirements fulfilled	

Table 18: WP5 objectives, evaluation strategy and indicators

3.5.1 Final Assessment

Objective 1 The main system requirements were extracted from the use case requirements. In other words, a technological roadmap was designed with the most important milestones and objectives to be achieved in the development of the ROBORDER platform. These requirements are the basis for the first version of the architecture that includes a more exact definition of the system requirements. The different modules were defined in this phase, and although they have been evolving and adding new ones, these modules can be grouped into the following categories of hardware (HW) and software (SW):

- HW Modules:
  - Central physical server
  - Communications system
  - Unmanned vehicles
  - Sensors
- SW Modules:
  - Mission management data exchange modules
  - Assets management data exchange modules
  - Sensors management data exchange modules
  - Alerts management data exchange modules

It should be noted that, this architecture proposal was finally modified to align with the final requirements of the end users. Specifically, a better long-range communications solution was designed to avoid security problems and guarantee the reliability of the architecture and coordination with the Ground Control Stations of the UxVs. A long-range local network with distributed antennas was the most suitable solution in this case, without the need for internet access. Finally, the task was completed with the final definition of the system requirements and the defined architecture. This was documented in deliverable D5.1, submitted and accepted.

Objective 2: The first part of ROBORDER software system integration was to implement a common approach to communicate between all components. The main requirements for this phase were to have a secured procedure to exchange data, ensure the correct structure of the exchanged messages and use a system fitting the requirement of each module. The most suitable option was to implement a message bus based on the publish and subscribe mechanism. The message bus acts as the central point for data exchange in the system, it secures the messages using an encryption method following the public and private keys principles and validates the structure of the exchanged message. The second part was the deployment of the software system, where it was decided from the initial phase of the project to use a strategy based on containerization. Containerization facilitates and standardizes the integration of all modules regardless of the technologies used by each partner. On the approach of important milestones, the modules were collected and stored into a common repository, then subsequently deployed and tested on the physical server. In order to deliver a TRL 7 system, the software system was tested with simulated data provided by the assets providers to validate a TRL 4. In later phases and simultaneously with the entire ROBORDER system, the software system was deployed and demonstrated in real conditions, in multiple operational environments. To integrate ROBORDER's software solution, this architecture must be understood as a system divided into three main blocks, in which each block represents a high level of functionality of the software systems and is made up of several modules that each satisfy a specific need. The referenced architecture blocks are:

- Mission and decision support components:

It contains the modules related to the interaction between the ROBORDER operator and the ROBORDER system. It contains the different User Interfaces (UI) and the relevant modules supporting the user in the definition and analysis of missions (Dashboard, Mission Editor, Visual Analytics ...)

- Threats detection and identification components:

It processes the raw data collected during the mission by the different assets and sensors. Each module provided by the technical partners, is responsible for detecting a specific type of incidents from unprocessed data (e.g. video feed, telemetry).

- Internal services:

It ensures the communication and data exchange between the software modules. It also allows the interaction between the hardware and software modules in ROBORDER system. They basically consist of a centralized database and a message bus system for the exchange of information.

Objective 3: To achieve the adequate hardware integration in the ROBORDER system, a preliminary definition of the hardware architecture was initially prepared, detailing the necessary requirements for the proposed use cases.

On the one hand, a technical assessment of the feasibility of integrating the different sensors as payload in the UxVs was made in order to define the hardware integration scope. Furthermore, technical requirements for the centralized server were defined between all the involved partners. In the next phase, the sensors developed in Work Package 2 were either integrated into the UxVs or integrated with the ROBORDER system as external sensors. A total of 6 unmanned vehicles have participated in the project's missions, which represents a total of 5 types of sensors, including (Dual, thermal, visible cameras, fluorimeter ...) On the other hand, a total of 2 external sensors (RF sensor and the Passive Radar) have been used for specific use cases (PUCs) whose platforms and networks have been deployed in real demonstration environments like the rest of the hardware systems. In the hardware related to the central server and communications system, the process carried out consisted of acquiring, developing and integrating the modules of the systems and then evaluating the capacities in internal field tests before the real demonstrations. Once the hardware capabilities of the system were integrated, the demonstrations in Portugal, Bulgaria and Greece allowed the validation of all the sensor characteristics. In addition, the communication system and the central physical server of the project were also deployed and evaluated during the demonstrations.

Objective 4: The basic architecture of the ROBORDER system has been defined from the beginning of the project with the first deliverable documents that have been milestones marked in the course of the project. The system integrations have been constant telematically during the development months, and then in person for the real demonstrations in the three countries involved in these field validations (Portugal, Bulgaria and Greece). On the other hand, some proposed tests such as those involved in the PUC1.6 use case were carried out semi-in-person to achieve the proposed objectives. In addition, during the last year, weekly meetings were held with the aim of integrating all the modules of the Final ROBORDER Integrated System. These activities were also reported in D5.5 and have prompted rapid development at the software and hardware level by all parties involved. In order to test the modules remotely in the early stages of the integration, a virtual server was deployed to make the test more dynamic. This virtual server contained the message services core and the database accessible on a public IP, allowing the different modules to be tested in a decentralized way without the need of being deployed in the physical server. This parallel architecture has been fundamental in the testing and validation process, since it has allowed each partner to configure their module iteratively, individually and then in coordination with the rest of the modules. Although it was used mainly for software integration purposes, it was also used to evaluate the system with the real output of the actual sensors, GCSs, cameras etc. Once the testing on the modules was finalized, they were dockerized in order to deploy them in the physical server for the final centralized architecture. To conclude the technical architecture from the software and hardware point of view was finalized and documented in deliverable D5.5 and finally the system was evaluated during the demonstrations in Portugal, Bulgaria and Greece. The use cases (PUCs) that have been evaluated are the following:

- First demonstration (Portugal)
  - PUC 3.1 Detection pollution accidents
- Second demonstration (Bulgaria)
  - PUC1-2: Detecting unauthorised land border crossing and signals from trespassers
  - PUC1-3 (demonstrated): Detecting unauthorised land border crossing
  - PUC1-4: Tracking high-tech smugglers
  - PUC1-5: Detecting the terrorist attack coming through cross border
  - PUC1-7: Tracking Organised Crime Activity in remote border areas
  - PUC2-1: Detecting jamming attacks
- Third demonstration (Greece)
  - PUC 1.1 (demonstrated) - Detecting unauthorized sea border crossing
  - PUC 1.8 - Detection, identification and tracking of maritime drug trafficking in a remote beach
- PUC 1.6 operational test (Italy)
  - PUC 1.6-Early and effective identification of passive boats moving offshore

(This operational use case will not involve any unmanned vehicles but it will evaluate the performance of the radar network and the integration of the MoniCA Platform with the ROBORDER system).

Objective 5: An integration plan was established to implement the system in the test environment during the three demonstrations of the project. For this, a preliminary coordination with the demonstration aerodromes was necessary made in order to assess the feasibility of the deployment of the system. Additionally, a Holistic Safety Operational Risk

Assessment according to SORA Methodology (AMC1 article 11 from EASA's IR 2019/947) was carried out in order to acquire authorization from Portuguese Civil Aviation Authorities (ANAC) to fly a 25 kg UAS in Portugal. The test environments were carefully evaluated prior to testing to ensure proper deployment of all assets. That is, analysis of operational requirements and action plans focused on the specific use cases (PUCs) of each demo. With this in mind, on-site evaluations were carried out. Finally, maintenance checks and revisions were performed after each demonstration to ensure the correct state of the system. Below is a brief description of the demonstration site and the vehicles (UxVs) involved in each operational scenario:

- First demonstration:

The first demonstration took place in the airdrome of Santa Cruz, Portugal during the week of November 16th 2020. This was the first time that a PUC with real unmanned vehicles was successfully performed. In this case, the fixed-wing UAV and the UUV participated in the demonstration.

- Second demonstration:

The second demonstration of the ROBORDER system took place on the week of the 21st June in the facilities of the Bulgarian Defense Institute in Stara Zagora, Bulgaria. For this demonstration, the involved vehicles were: 1 Fixed wing UAS, 2 Transformer multirotor UAS, 1 UGV mobile robot.

- Third demonstration:

The third ROBORDER demonstration is scheduled took place during the week of the 28th of June with the collaboration of Hellenic Navy. It involved aerial and maritime unmanned vehicles (fixed-wing UAV and the USV) and the aim was to evaluate the maritime PUCs.

3.6 WP6: Demonstrations and evaluation

The main objective of this WP is to evaluate the developed platform and train the border authorities and LEAs for using it. WP6 is articulated in five tasks, the first task (T6.1 deals with the identification of an evaluation methodology and the definition of the project KPIs used to assess the performances of the ROBORDER platform. The second task (T6.2) is about the training of the operators through a series of training events synchronized with the demonstration events. The third task (T6.3) generates from the CMRE know how in Modelling and Simulation (M&S); M&S techniques are used within ROBORDER to support the CD&E and V&V of the ROBORDER platform, both as a tool for technical partners and end-users, complementing the live tests. The fourth and fifth tasks (T6.4-5) are the main tasks of the work package, devoted to the organization of the live events for testing ROBORDER platform performances and demonstrating it to an end-user based audience. The data collected during the live events are used to compute the KPIs defined in T6.1 supporting the quantitative and qualitative evaluation of the ROBORDER platform.

WP	6		
WP Leader	CMRE		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**End-user evaluation plans and methodology** The aim of this task is the definition of a common evaluation methodology and a testing plan for all the defined PUCs.	T6.1	MS1, MS3-MS5 (End-Month: M38)
2	**Operator Training** In the context of this task, the appropriate training courses will be developed for the corresponding personnel to be familiarized with the framework.	T6.2	MS1, MS3-MS5 (End-Month: M45)
3	**Preparation and implementation of test-plans as simulated exercises** The main output of this task will consist on a test-bed capability	T6.3	MS1, MS3-MS5 (End-Month: M44)

	based on M&S that will enable the testing of the ROBORDER developments in early phases before its deployment and the final operational testing.		
4	**Demonstration and evaluation for marine border threats detection** In this task, the scenarios related to marine border threats will be operationally tested based on the evaluation plan.	T6.4	MS1, MS3-MS5 (End-Month: M45)
5	**Demonstration and evaluation for land border threats detection** In this task, the scenarios related to the land border threats will be operationally tested and evaluated based on the evaluation plan.	T6.5	MS1, MS3-MS5 (End-Month: M45)
WP Evaluation Strategy			
A/A	**Evaluation strategy description**		
1	The evaluation strategy that was followed included the definition of the proper KPIs which were identified by the end-users and the corresponding evaluation methodology.		
2	The under-development training courses will be evaluated based on the end-users' satisfaction.		
3	Simulated scenarios and demonstrations will be evaluated based on the accuracy and the use case coverage.		
WP Indicators			
A/A	**Highest expectation**	**Lowest expectation**	
1	100% coverage of the identified KPIs	75% coverage of the identified KPIs	
2	100% competence and confidence of the trainees as operators of the system.	75% competence and confidence of the trainees as operators of the system.	
3	100% alignment between the results of the real and the simulated scenarios.	75% alignment between the results of the real and the simulated scenarios.	

Table 19: WP6 objectives, evaluation strategy and indicators

3.6.1 Final Assessment

Objective 1: progress 100%. The evaluation methodology has been developed and used throughout the whole project life cycle and especially during the ROBORDER live events. Expectations are met. Deviation reported: the task should have been considered since the beginning of the project as a long lasting one; finishing at the end of the WP. This is due to the fact that the progresses in the development of ROBORDER platform have an impact on the KPIs list, which has been updated as long as the platform matured.
Objective 2: As part of the task T6.2 of WP6, the main task of the ORFK was to develop a complex operator training programme. The implementation of the training went smoothly, with all the "trainees" involved (13 in total) completing the training. The content of the training covered the basic concept of the whole Roborder project, the requirements for the applicability of the system, the most important data protection and ethical rules, the legal framework (e.g. the regulatory background for the applicability of robots) and included a comprehensive test module of about 30 questions, during which the trainees could demonstrate their knowledge in electronic form. It is important to underline that one of the tasks undertaken in T6.2 was to develop a gamification-based training system, including gamification elements. This has been achieved by developing a method whereby the trainee can obtain virtual ranks from the beginning of the training and progressively higher ranks as the training progresses. A Roborder certificate was also developed to certify the completion of the training and was given to the participants after the training. In addition to the above activities, ORFK participated in both demonstration-testing weeks in the border police professional cooperation, in the online monitoring of the activities, in the evaluation (e.g. discussion of good practices, lessons learned, etc.) and in all online events as a contributing consortium partner. The original project plan had been to combine the training with the testing and demonstration in Hungary, where the experts contracted for the project would have provided face-to-face training as trainers, but due to the relocation of the Hungarian

event to Bulgaria and travel restrictions caused by the COVID-19 pandemic, the consortium decided to go ahead with the full digital training. In practice, this was done by delivering the complete training system (including content, software, related documentation) electronically in encrypted form to the BDI and HMOD coordinators who were involved in the training and who, during the demonstration, carried out the training on electronic devices (laptops) with the designated persons. The DKM system for the training process was initially planned to be deployed nonetheless, ORFK did not proceed with the purchasement of the software tool. ORFK has taken steps to contact the company (Ekon) that previously developed the platform in the FP7 project asking for a subscription quote. The price was identified as 20K € including all its features that could be applicable for sharing training materials, training exams, related textbook and for conducting the whole operator training. Nevertheless, considering the scale of the above mentioned cost, as this acquisition was not planned when the project idea was compiled, it could not be financed out of the budget granted to ORFK. Thus, the training courses were developed using open platforms.

Objective 3: progress 100%. The outcome of task 6.3 exceeded the original expectations. The M&S capability has been developed to embrace all the components of ROBORDER platform and has been used within the project life cycle to support the organization of the live tests events as well as tool for CD&E for ROBORDER platform. The M&S capability has also been validated through the use of the data collected during ad hoc tests and live events.

Objectives 4-5: The scenarios related to the land and marine border threats have been operationally tested and evaluated in Portugal, Bulgaria, Italy and Greece according to the evaluation plan and associated PUCs. Based on the unauthorized border crossing and pollution detection scenarios an analysis and report on the experiences and assessment results from the use of the ROBORDER platform have been made. The task is successfully concluded, meeting all expectations according to GA without any deviations.

The demonstrations were organized to meet the following objectives:

- Evaluate the functionalities of the 2nd prototype in a real operative environment for pollution detection scenario.
- Evaluate the functionalities of the 2nd prototype in a real operative environment for land border security.
- Evaluate the functionalities of the final system in a real operative environment for border security.
- Demonstrate the use of the ROBORDER platform to support the objectives of each PUC, and coordinate UxVs operations including:
    - Detection of a polluted area.
    - Detection of multiple groups of trespassers passing the boarder on foot (a large group of 10 trespasser splitting in two groups of 5 people);
    - Detection of a van/truck crossing the border;
    - Detection of an UAV crossing the border;
    - Detection of a GPS spoofing and communication jamming attack on border security UxV.
    - Detection of small vessel approaching the shore
    - Detection of a small vessel entering a port
    - Enlarge the active radar coverage using a passive radar receiver.
    - Share detections with LEAs.
- Perform a live test of the ROBORDER platform in presence of external end users invited to assist to the demonstration.

The demonstrations and the operational tests were organised during virtual coordination meetings involving all the demonstration participants and contributors that occurred weekly since the first quarter of 2020.

During these meetings, the participants agreed upon:

- The demonstration detailed scenarios to guide the execution of the tests to cover all the ROBORDER PUCs,
- The KPIs to support the evaluation of ROBORDER components,

- The participants to the demonstration
- The red team activities
- The logistics (location, transportation),
- The demonstration technical requirements (power, communications),
- The legal and the ethics requirements (authorizations to the use of drones and area interdictions, permission to enter the demonstration facilities, privacy informative and non–disclosure agreement for external participants),
- The actions necessary to ensure the successful outcome of the demonstrations and tests.

In addition to these regular virtual meeting, the following events were organized to support the demonstration:

- Weekly Remote Integration Tests, meetings organized since the end of 2019 within the scope of WP5 and with the support of WP6 as a way to mitigate the risks in consideration of the limitations imposed by the outbreak of COVID-19. The tests proved very valuable to refine the architecture of the system and test the functionalities of the ROBORDER components well ahead of the demonstration. The meetings focused on testing the correct behaviour of the system components and to ensure the communication between the different nodes involved in the demonstrations.
- Simulations, reported in Deliverable D6.5, developed in support of the organization of ROBORDER demonstration and the Verification and Validation (V&V) process of the ROBORDER UxVs (UGVs and quadcopters) and sensors (Radar).

3.7 WP7: Dissemination and exploitation

WP7 aims to contribute to the market awareness, by disseminating information on the project, its progress and results and to ensure the exploitation of the results in academia, industry and especially in SMEs, addressing end-users' needs. Collective effort to deliver the work has been focused on the planning of dissemination, analysing standardization and collaborations, developing communication materials and channels, conducting market analysis, creating business models and the plans for exploitation and sustainability of project results. As can be seen in the table below, several milestones mark the progress of the work package.

WP	7		
WP Leader	Everis		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Dissemination and events organisation** This objective focuses on the elaboration and update of the ROBORDER dissemination plan.	T7.1	MS1, 3, 5 (End month: 46)
2	**Communication** This task focuses on developing and updating the dissemination material to all stakeholders.	T7.2	MS1, 3, 5 (End month: 46)
3	**Standardisation and collaboration with other projects** This objective aims at guaranteeing the interoperability of the different subsystems and focusing on the collaboration with other projects.	T7.3	MS1, 3, 5 (End month: 46)
4	**Market analysis** This task analyses the potential market opportunities for the different outcomes of the project.	T7.4	MS1, 3, 5 (End month: 14)
5	**Business model** This objective aims at defining the initial business plans that will	T7.5	MS1, 3, 5 (End month:

	support the commercial exploitation.		46)
6	**Exploitation and long-term sustainability plan** This task focuses on the development of an innovation and exploitation plan that will be launched as soon as ROBORDER's expected outcomes are fully documented.	T7.6	MS1, 3, 5 (End month: 46)

WP Evaluation Strategy

A/A	Evaluation strategy description
1	The evaluation strategy of this task will focus on: ⇒ Request internal, ongoing dissemination activities reports from each partner.
2	For the evaluation of the communication plan, ROBORDER will focus on: ⇒ Assess the time that all relative material has been created ⇒ Assess that all material will be updated regularly
3	For the evaluation of ROBORDER's standardisation and collaborations with other projects: ⇒ Assess the connections with possible members by using all the partners' connections with stakeholders ⇒ Asses the connections with possible members through other projects
4	For the evaluation of the market analysis, the responsible partners should focus on: ⇒ Show that the system will enter the market and provide benefits to the stakeholders
5	For the evaluation of the business model: ⇒ High level of user-friendliness ⇒ Relevance to multiple modules
6	For the exploitation and long-term sustainability plan, the responsible partner should: ⇒ Evaluate the pilots' outcomes and identify the strengths of the system ⇒ Use the NoI to evaluate the system and the needs it addresses ⇒ Specify the targets to be reached, define the actions required, specify which partners are to take these actions, and present them in a time plan extending at least 2 years after the completion of the project.

WP Indicators

A/A	Highest expectation	Lowest expectation
1	⇒ 100% completion of all tasks/activities by the foreseen deadline ⇒ Receiving input from 100% of the partners. ⇒ Participate in 20 conferences/events ⇒ Publication of 25 scientific papers	⇒ 75% completion of all tasks/activities by the foreseen deadline ⇒ Receiving input from 50% of the partners. ⇒ Participate in 6 conferences/events ⇒ Publication of 10 scientific papers
2	⇒ 20% increase in website traffic per year ⇒ 20% increase per year and activity on at least 2 social media platforms. ⇒ A private section for safe access by project partners to be used for collaborating purposes ⇒ Create account in all major social media ⇒ Create a project presentation, leaflet and factsheet	⇒ 10% growth in website traffic per year ⇒ A private section with minimal material and minimal use ⇒ Create only one social media account ⇒ Create only one presentation
3	⇒ At least 5 synergies with other projects achieved.	⇒ At least 3 synergies with other projects achieved
4	Conducting a market analysis for all aspects of the potentially relevant markets that the system will address.	Conducting a market analysis only for the most significant markets that the system will address.
5	Create business models for all modules that are developed	Create business models only for the core modules
6	Create specific and measurable targets to be reached in 2 years period after the project's completion with specific target for each partner and for the consortium.	Create more generic and qualitative 2 years action plan for the whole consortium.

Table 20: WP7 objectives, evaluation strategy and indicators

3.7.1 Final Assessment

Objective 1: Dissemination activities performed in the basis of the strategic guidance provided by ROBORDER's Description of Action (DoA). Partners shared their dissemination activities in the common repository of the project, that was updated monthly. ROBORDER project has participated in more than 20 conferences and published 45 scientific papers, took part in several workshops and support online content dissemination. The pandemic of COVID19 decreased dissemination activities mainly during the last 16 months of the project and created minor deviations to the initial dissemination planning. For more information regarding the dissemination results refer to D7.5 Final Dissemination Report that has as a submission date the 31st of August 2021.

Objective 2: As far as the communication of the project is regarded, all dissemination materials (Presentation, Leaflet, Factsheet) have been created on time and are updated regularly in the website of the project, so that the information that is communicated to the public is not outdated. The website and social media (LinkedIn, Facebook, Twitter) of ROBORDER were launched in the beginning of the project. In addition, a private repository used only by project partners was created to enable collaboration and easy access to the project's material. However, due to the negative press coverage that the project drew, the EC guidelines suggested a reserved dissemination of the project, resulting only to the publication of its highlights, keeping a low profile in the website and social media. Lastly, the task is 100% completed according to the evaluation strategy but deviated from the highest expected indicators, in order to be in compliance with the EC guidelines of the second review meeting. For more information on the users and analytics of the website and social media refer to D7.5 that has as a submission date the 31st of August 2021.

Objective 3 progress 100%. The associated activities concerned the monitoring and reporting on the use, within the ROBORDER project, of the standards adopted in the development of the project platform and of collaborations with other projects. Standards enabled the interoperability of all ROBORDER subsystems and third party elements that contribute to the multi-domain border security platform and to execute operations. ROBORDER complies with eighteen de facto standards and best practices, including: information models for exchange and interoperability of maritime and border security data, data to multi-domain control stations and augmented reality devices, map tiles, and temporal information; architectural models for interoperable machine-to-machine IoT technologies and simulations, safety regulatory frameworks, including regulations for safe UxV mission operations; guidelines for architecture development; a vehicles mission specification language; and a user experience best practice. The standardisation activities included standard adoption and alignment activities, standard enrichment and implementation activities, standard modelling and implementation activity and the participation to 1 standard committee. Collaborations with other projects were also monitored and reported. These aimed at facilitating the project innovation, the exchange of knowledge and the application of best practices in the areas of security, surveillance and monitoring. ROBORDER partners collaborated with twenty-two other projects in multiple domains of interest underwater in the area of surveillance, security and safety, monitoring and management, and autonomy, including: 15 European Horizon 2020 projects, 2 European Defence Agency projects, 1 European Space Agency project, and 1 European structural and Investment funds project; 1 International Centre for Migration and Policy Development project; 1 Federal research project funded by the Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center. The collaborations mainly targeted situational awareness, border management, security and surveillance, integrated command, control and coordination platforms, and pertained to several research areas overlapping with ROBORDER interests, mainly information fusion and Internet of Things.The ROBORDER standardisation and external collaborations activities have been analysed and reported with respect to their focus areas, domains, topics and types of activities, and associated to operational ROBORDER tasks, in order to analyse the status and overview the progress of the standardisation and project collaboration activities along the project execution. The data in support of this activity have been prepared with the collaboration of the reference ROBORDER partners. After a preliminary collection of information at executive board meetings, a structured focused survey was organised and periodically revised in collaboration between CMRE and the involved partners. The data collection, analysis and reporting methodology comprised four steps, including: 1) a structured collection of information, reviewed interactively with the responsible partners. 2) a preliminary exploration of results and their reasoned harmonisation to prepare the data for the analysis; 3) the analysis and summarisation of data with graphical analytics. 4) data periodically revision and update. After the first structured collection in June 2020, the ROBORDER partners were requested to revise their contributions and amend or integrate any missing information in December 2020-January 2021, and a second time in June 2021.

Objective 4 has been achieved, comprising the identification and characterization of market actors, analysis of the industry and its trends, and the potential market drivers. The outcome was within the expected.

Objective 5 has been accomplished, using the results from the market analysis and exploitation plans as basis to draft the business models, as well as potential business strategies. End-users feedback was crucial in directing the business strategy towards addressing their needs.

Objective 6 has been completed, including the development of exploitation plans, which will ensure the sustainability of the project results after the end of the project. Everis assisted partners in gathering, treating, analysing and displaying the information of the final individual and joint exploitation plans, as well as sustainability strategies such as letters of support, services creation and identification of calls for funding directed to further development of results.

3.8 WP8: Project Management

In this section the overall progress of the WP8 – Project Management Work Package will be presented. This Work Package refers to the management of the project's time and budget, the coordination of activities and the monitoring and adjustment of the implementation plan and data management, if necessary.

WP	8		
WP Leader	CERTH		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	**Project Management** This task focuses on carrying out all the coordination and planning activities needed to manage and coordinate the project.	T8.1	MS1, MS3-5 (End month: 46)
2	**Project administration, reporting and financial management** This task provides support to administration and financial management of the project.	T8.2	MS1, MS3-5 (End month: 46)
3	**Quality assurance and risk management** The aim of this task is to develop the quality assurance guidelines, monitor the quality of the scientific output, and detect risks and take corrective actions where necessary.	T8.3	MS1, MS3-5 (End month: 46)
4	**Management of confidential information** This task will create a Data Management Plan (DMP) as a document outlining how research data will be handled during a research project and after it is completed.	T8.4	MS1, MS3-5 (End month: 46)
WP Evaluation Strategy			
A/A	**Evaluation strategy description**		
1	The evaluation strategy for this task includes:		

	⇒ Request internal, 6-month periodic activity and expenditure reports from each partner ⇒ Assessment of the completion (%) of each task/activity by the time foreseen based on the information obtained from the 6-monthly internal activity reports and the interviews with the responsible partners. ⇒ Assessment of the budget figures as reported by the partners in the 6-month internal expenditure reports in light of the overall budget figures and their extrapolation to the total duration of the project.	
2	The evaluation strategy for this objective involves: ⇒ Assessment of the successful and timely completion of the requests by the partners of Consortium and the Commission ⇒ Assessment of the timely submission of the deliverables. ⇒ Assessment of the successful management of the meetings	
3	The evaluation strategy of the task includes: ⇒ Assessment of the research progress within a WP as documented in the internal periodic reports, deliverables ⇒ Assessment of the all the components progress within each WP as documented in the internal periodic reports, deliverables	
4	The evaluation strategy involves the development of high quality DMPs and reported in the relevant deliverables (D8.2 and D8.4).	
WP Indicators		
A/A	**Highest expectation**	**Lowest expectation**
1	⇒ 100% completion of all tasks/activities by the foreseen deadlines ⇒ Expenditure of funds proportionally to the lifetime of the project	⇒ 75% completion of all tasks/activities by the foreseen deadlines ⇒ Justified expenditure of funds, in accordance with the EC regulations.
2	⇒ Completion of all requests by the partners of the consortium and the Commission within 7 working days to the satisfaction of the inquirer ⇒ Submission of the deliverables by the deadline established in the work plan ⇒ Exhaustive treatment of all topics foreseen in the agenda of a meeting	⇒ Completion of all requests by the partners of the consortium and the Commission within 14 working days to the satisfaction of the inquirer ⇒ Submission of the deliverables within the contractually fixed 45 days after the deadline established in the work plan ⇒ Treatment of all topics foreseen in the agenda of a meeting to an extent that allows for the continuation and successful completion of the topics over distance
3	100% fulfilment of the criteria/highest metric figures established for a given task/activity.	Meeting the minimal requirements/performance figures established for a given task/activity
4	100% fulfilment of the established criteria	Meeting the minimal requirements for the quality of the corresponding deliverables.

Table 21: WP8 objectives, evaluation strategy and indicators

3.8.1 Final Assessment

Objective 1 According to the evaluation strategy, the internal 6-month activity and expenditure reports have been completed successfully. All 45 deliverables were submitted, as well as the previously rejected, D2.3, D5.4, D6.4, D3.1 and D4.1, were resubmitted according to the 2nd review meeting comments and approved. Due to the COVID-19 pandemic, an evaluation of the situation was performed, leading to a mitigation plan that involved an extension of the project to 52 months and a shift in the location of the second demonstration from Hungary to Bulgaria, as the former organizer of the 2nd demonstration, ORFK, declared inability to execute the required scenarios thus, the beneficiary was substituted by BDI. Following the aforementioned actions of the last amendment, all planned demonstrations and pilots were executed in time and the completion of tasks/activities

reached 100%. Lastly, the expenditure of funds has been assessed as proportional to the lifetime of the project, taking into consideration the project's extension in the amendment.
Objective 2 All deliverables were submitted on time, following the guidelines of the project officer, in case an obstacle occurred. Efficient communication was established between the project officer and the coordinator, who worked as delegates, in order to transmit raising issues of the partners of the consortium or the project to the Commission. By monitoring the 6-month financial report, any deviations detecting in the Grant Agreement planning were pinpointed and well justified for the final review. In addition, the project's repository was kept updated throughout the project to enable the intra-communication between partners and keep minutes and results of weekly, bi-weekly meetings and operational tests of ROBORDER's platform.
Objective 3 The risk management has been established via a common risk inventory shared with all the consortium and mitigation actions have taken place where it was necessary. The quality check of the expected outcomes undergone 4 review stages, 2 internal, 1 security, 1 ethics and one final quality check by the coordinator before submission. Also, quality of technical results was monitored continuously through (bi)weekly meetings and operational tests of the ROBORDER platform to ensure efficiency and operability. Consequently, objective 3 has been fulfilled to the highest expectation.
Objective 4 An update in the Data Management plan has been made in D8.6 to be compliant with the current EU recommendations regarding ethics and security issues. Furthermore, the review comments of the second periodic review concerning the Data Management Plan, have been taken into account as was described in Section 2.0. In conclusion, as all deliverables followed the proposed DMP, the objective indicator was assessed as 100% successful.

3.9 WP9: Ethics

In this section the work conducted within the context of WP9 is explained based on the evaluation strategy and the set indicators found in deliverable D8.4 as well as in the table below. WP9 focused on ensuring the project's compliance with the project's Ethics Requirements, the European Union's Guidelines as well as with the General Data Protection Regulation (GDPR).

WP	9		
WP Leader	CERTH		
WP Objectives			
A/A	**Objective**	**Task**	**Milestone**
1	This objective ensures compliance with the "Ethics Requirements" set out in this work package.	-	-
WP Evaluation Strategy			
A/A	**Evaluation strategy description**		
1	The evaluation strategy of this WP focuses on acquiring all the necessary documentation in order to be compliant with the suggested European Guidelines on Ethics and Data Protection: ⇒ UxV authorizations for operation ⇒ DPO ethics approvals regarding data protection ⇒ Signed informed consent for involving humans in demonstrating real scenarios and on forming certain ethical and data protection rules that should be abide by the partners that are involved in the demonstrations/operational tests: ⇒ Ethical Code ⇒ Data Protection Rules		
WP Indicators			
A/A	**Highest expectation**	**Lowest expectation**	
1	Acquire all needed documentation before commencement of any relevant work and	Acquire all needed documentation before commencement of any relevant work and	

	submit codes and rules in the respective deliverable.	submit drafts on codes and rules.

Table 22: WP9 objectives, evaluation strategy and indicators

3.9.1 Final Assessment

Objective 1: within the context of Objective 1, the consortium has devoted great efforts in ensuring the project's compliance with the set Ethics Requirements. In more detail, (i) all documentation/authorisations regarding the operation of UxVs during the project's demonstration were acquired before commencement of any relevant work, (ii) all information sheets and informed consents were distributed and collected from involved human participants in the demo before their actual involvement in the project's research activities, (iii) all needed ethics approvals from competent and independent ethics committees were acquired from all partners of the consortium that had the capacity to contact such a committee, (iv) in case this was not possible for some partners (due to the nature of their organisations) detailed ethics and data protection policies were requested that were depicting the way in which all human participants and their data will be safeguarded and protected, (v) explicit Data Protection Rules and an Ethical Code that should be followed by all users of the ROBORDER platform were created and added in deliverable D8.6 and D6.9 in order to be addressed both to users within the Consortium as well as to any future user of the platform. As additional measures for ensuring the project is compliant with the European ethics requirements, a detailed Data Protection Impact Assessment was conducted and kept updated throughout the project's lifetime and two Ethics Implication Assessments were also performed; the first of which was mostly addressed to the ethics implications the system will have within the context of the execution of the project's demonstration and the second of which was addressing the impact the platform will have when it reaches the market and it is deployed in real life. Taking all the above into consideration, all indicators were met to the consortium's highest expectations.

4. Impact

In this section ROBORDER's impact will be analyzed. The impact will be assessed in categories, firstly the project's contribution towards the expected impact of the call will be presented and then the project's footprint in economy, society and technology.

4.1 Project contribution towards topic's expected impact

- **Further development of the European Border Surveillance System (EUROSUR)**
  The integration of ROBORDER platform contributes to EUROSUR, as it guarantees a better overview of border territories as the surveillance relies strictly on moving assets and sensors. The system is enhanced with assets like weatherproof unmanned vehicles, sensors and can incorporate advanced radars networks, however the innovation of the platform lies on the new operational concepts and communication strategies used as well as the cutting-edge detection models. In addition, the maritime domain benefits from simultaneous activities, such as monitoring, detecting, reporting and suggesting course of action that enables LEAs to stop unlawful entry into the EU area.
- **Provision of more information that may be exchanged across sectors and borders through the Common Information Sharing Environment (CISE)**
  One of ROBORDER's objectives is to provide situational awareness through a highly autonomous system that requires only human supervision. This situational awareness is succeeded and enriched by merging detection data based on the CISE (Common Information Sharing Environment) and combining different sources of data to

empower its usefulness and usability when shared on the European network with other states.

- **New technologies for autonomous surveillance systems**
ROBORDER aims at providing a fully autonomous multi-robot systems, where human operators contribute only for inspection and supervision purposes. The heterogeneous robots are equipped with different sensing abilities that are coordinated by a plug-n-play framework and performs seamless transition between different surveillance tasks while operating. As a result, and by taking the existing static infrastructure into consideration, the operators are enabled to easily command and control the overall team of heterogeneous assets with the minimum workload.
- **Improved, cost-effective and efficient unmanned platforms for border surveillance systems, and the detection of marine pollution incidents**
The unmanned systems have made a strong entrance in the market providing effective solutions while keeping human resources from entering in dangerous situations. ROBORDER offers a platform that is designed to operate in extreme weather conditions providing high integrability of its assets. By taking advantage of the variety of available UxVs, it offers high system flexibility that is able to serve a large scale of use cases and scenarios without requiring a specific system for different missions and locations or high maintenance efforts. Furthermore, the small human involvement, that minimises the need of highly skilled and highly paid personnel in combination with the capability of the system to operate autonomously accomplishes significantly less effort, time and costs compared to already existing systems.
- **Adaptation of long-tested technologies to the specific requirements of borders control area**
ROBORDER's concept focuses on bringing together many advanced technological achievements with the goal of augmenting their collective impacts and serving the specific requirements of border surveillance. The platform consists of different components and sub-systems that are already available in the market but not used before in such an innovative manner in border surveillance. Examples of this kind of components and sub-systems are the unmanned vehicles, the optical and thermal cameras for use on board of the vehicles, the sensors and the photonic-based radar network. In addition, cyder-security algorithms and techniques for the protection of the platform, but also advanced user interface and decision support systems are part of the ROBORDER's concept of combining already known techniques in border control areas, bringing new horizons to the sector.
- **Agents and command and control systems interoperable with existing, multi-country European infrastructure**
The platform of ROBORDER is based to already existing swarm operation systems that have been tested successfully in previous projects such as NOPTILUS and RAWFIE projects. Moreover, end-users that use CISE, guarantee that the operability of ROBORDER is well structured and the criteria required fully met. Lastly, targeted dissemination and communication activities were planned, to emphasize the importance of of using the European sharing platform by all European end-user entities.

4.2 Economic Impact

Economic Impact Expected	How to measure the impact
Reduce the cost of maritime border surveillance	By measuring the differential Cost of maritime border surveillance targeted by type of surveillance: - Coast guard - Maritime Authority - Rescue

	- Police Authority, etc.

The ROBORDER project has developed an autonomous sea surveillance system, which significantly lowers costs in comparison to traditional surveillance methods at several levels, including initial cost, personnel training, maintenance and additional operation costs. In addition, the multi-domain border security platform integrates autonomous vehicles in sea border security scenarios. On top of that, the standardisation of the border security information data exchange will lead to more efficient operations.

Economic Impact Expected	How to measure the impact
Reduce the cost of land surveillance	By measuring the differential Cost of land surveillance targeted by type of land surveillance: - Rivers surveillance - Lakes surveillance - Mountain surveillance - Rescue - Police Authority, etc.

Likewise, the ROBORDER project has developed an autonomous land surveillance system, which significantly diminishes costs compared to traditional surveillance methods, including initial costs, personnel training, maintenance and other operation costs. The interoperability framework and the use of modern technologies will lead to a more efficient land surveillance and to the creation of rescue roadmaps and protocols for EU agencies rescues.

Economic Impact Expected	How to measure the impact
Increase the efficiency of surveillance teams and provision	By measuring the differential in terms of efficiency of surveillance operations targeted by types between current operations and reasonable expectations inferred from tests done throughout the project, including demonstrations

WP7 has integrated factors that will increase the efficiency of surveillance teams and provision. For example, the market analysis will raise awareness towards the industry standard, which might reduce outdated practices, and promote new best practices. In addition, exploitation plans will provide opportunities of exploitation which could benefit partners in the short and long-term, optimising the efficiency of their surveillance teams.

Economic Impact Expected	How to measure the impact
Reduce the cost opportunity of having personnel and provision in surveillance points where there aren't incidents	By measuring the increase of the incident detection to orientate the operations

ROBORDER will contribute to the detection of incidents by improving forecast capabilities of LEAs. This has been done with the use of high-end technology (IoT, AI, etc) and data integration. In addition, the standardisation through the combination of interoperable frameworks will also reduce the personnel costs. Standardisation was implemented based on EU standards, which assisted LEAs in becoming more accurate, while reducing the risks and costs of manual surveillance. Prevention has been strengthened through the automated data collection and integration, operated by the data gathering module.

Economic Impact Expected	How to measure the impact
Increase ICT industry related to robots and security	By measuring the number of stakeholders that are making use of the outcomes of the project, including other projects that are reusing the knowledge and experiences disseminated. The latter will be measured taking into account the number of times the results are referenced.

The individual and joint exploitation plans of ROBORDER partners provide an overview on the organisations planning to use the outcomes of the project. They comprise not only internal partners strategies, but also collaborations with other projects which could potentially reuse the project results. In summary, so far 66 individual exploitation plans have been drafted and 15 exploitation partnerships have been identified.

Economic Impact Expected	How to measure the impact
Reduce the time to integrate new robots and sensors	By measuring the time to integrate a sensor/robot in the platform, since it is expected that new generation of sensors and robots could be used in the later stages of the project

The use of standards and ICT- interfaces aimed to decouple the sensors and robots from the platform, thus ensuring that new generations of robots and sensors can be deployed without core changes to the platform, which would reduce the time of integration. As such, the independent modules of the platform will contribute to reduced costs, resulting from the reduced integration time.

Economic Impact Expected	How to measure the impact
Reduce the cost to deploy a surveillance solution	By measuring the number of users/stakeholders who will be using the system, or some of its components, within their own surveillance solutions.

Business plans for services have included 22 project results from 16 partners who participated in the identification of services that will be generated from the platform. The number of users/stakeholders who will be using the system is considered in this identification and the impact is measured in a 5-year span. In addition, as mentioned beforehand, several individual and joint exploitation activities are planned for the aftermath of the ROBORDER project, which are detailed in the D7.8 in their final version.

4.3 Societal Impact

One of ROBORDER's focal points was the impact the system will have on society when deployed in real-life and more specifically on the operations of border authorities' personnel as well as on citizens.

- **Impact on how border authorities monitor and secure external borders**
  With ROBORDER's platform, land and maritime authorities have the opportunity to timely and accurately **detect illegal activities** (e.g., migrant smuggling, human trafficking). In more detail, ROBORDER's platform uses commercially available unmanned vehicles (UxVs) in combination with radars and sensors (such as passive radars, passive radio frequency signals, thermal cameras and infrared cameras) in order to provide border authorities with the information they need (**early warning**) and to **support their decision-making process**; leading in this manner to reduced response time to detected events (be it criminal acts or people in need). Additionally, the system will assist authorities when having to deal with unapproachable terrains with the use of a variety of unmanned vehicles (land, aerial, marine) that could monitor the area of interest without putting in risk the wellbeing of the border authorities' personnel; by not involving them directly in an unknown and perilous situation and by equipping them with the appropriate tools to handle each situation. This could consequently be translated into less personnel or training costs as fewer people are going to be involved in these operations. Additionally, the use of smaller, commercially available UxVs can also result into reduced costs both in purchase and in maintenance. Finally, the software used for the integrated sensors/radars is more affordable to upgrade rather than purchasing a new solution (in case the system needs to be updated based on new needs arising). Since the current solution reaches up to TRL7, there is much room for further development meaning that the system could be adjusted to fit specific needs of future users and could help to further

safeguard European borders from irregular migration and transnational organised crime.

- **Environmental and other societal impacts**
  As a result of the above, border authorities will have the capacity to handle large-scale crises in a timely manner, leading in this way towards an enhanced feeling of security among European citizens. Additionally, the system could have a significant impact of human lives and it will be able to monitor unapproachable terrains in order to ensure that no physical harm is inflicted on individuals trying to cross the European borders (e.g., migrant smuggling through uncertain and questionable means of transportation). Moreover, ROBORDER has an environmental aspect that should be mentioned at this point. An AI-based model has been deployed and validated under real operational scenarios in order to identify oil spills over sea surface. As a result, immediate and adequate measures could be taken by the respective authorities in order to avoid further environmental damage.

4.4 Technical Impact

Technical Impact Expected	How to measure the impact
Provide an overall border security solution, integrated with current systems and effective for both maritime and land borders	Compared efficiency and efficacy of the ROBORDER system in various land and maritime scenarios with traditional assets and methods that don't use autonomous vehicles

Following the consortium's contractual obligations, a fully operational system is to be delivered and demonstrated in multiple and diverse real operational scenarios. The final prototype involves the use of different types of unmanned vehicles, aerial, land and maritime means. In all the under study use cases, border agencies use mostly human patrols equipped with relevant infrastructure inserting multiple restrictions such as inaccessible territories and/or widest maritime territory. Towards substituting such obsolete practices, the ROBORDER framework demonstrated its applicability and flexibility in various relevant scenarios.

Technical Impact Expected	How to measure the impact
Enabling response to threats within minutes	Time of asset deployment in different scenarios during ROBORDER demonstration events

The system's assets are easy to be deployed and flexible to be operated using intuitive and user-friendly frameworks. Deployment is kept minimum by retaining their status at a "hibernation mode" waiting for mission commands from the main framework. Therefore, the overall response time that is required from border agencies to properly act after a potential illegal event can be significantly decreased in comparison with the operation of a human patrolling unit.

Technical Impact Expected	How to measure the impact
Enabling efficient and effective operation of heterogeneous multi-asset system by a single operator	Number and types of assets managed by single operator; Efficiency and efficacy of automatically generated flags; Time of threat detection, classification and identification, and of decision-making in different scenarios during ROBORDER demonstration events

The novel multi-robot coverage path planning algorithm developed specifically for the needs of the project, guarantees that any mission can incorporate as-many-as-the-operator-decides vehicles, in order to scan an operational area and acquire increased situational awareness. In addition, the robust multi-threading mission management system provided, allows the simultaneous generation, management and execution of multiple multi-robot missions at the same time. This way, a single human operator in the dashboard of the ROBORDER's system can design, deploy and manage any number of autonomous vehicles, operating simultaneously, even with different defined high-level objectives

Technical Impact Expected	How to measure the impact
Improved payloads for UxVs, Contributions to UxV cyber-security, Contributions to UxV CommInt	Compare operational efficacy of pre-existing systems with ROBORDER's prototypes during project demonstrations

The core sensory systems that were used during the demonstration events were mostly visual cameras to identify specific objects of interests that contribute to a potential illegal activity. Nonetheless, the aim of the project is not only focusing on delivering highly adaptable surveillance system with improved detection capabilities but also a fully secured system which can identify potential communication intrusions. Within this scope, a service under T3.4 has been developed and incorporated to secure the system from external attacks. In addition, the communication links between the assets and the main ROBORDER framework were selected according to their active distance but also, for the security protocols that are adopted to safeguard the exchanged data. Additional details for the local network deployment and the corresponding modules are reported in D5.5 "*Final Integrated ROBORDER System*" [RESTREINT UE/EU RESTRICTED].

Technical Impact Expected	How to measure the impact
Photonic radar network	Lab test on the subsystems and the whole assembled system. Check of the obtained performances compared with the system design. Analysis of the employed DSP techniques.

The performance of the photonics radar network has been analyzed in the lab both at subsystem and at system level, meeting the expectations from the design phase. The processing module has been deeply tested with simulated input data, again meeting the expected performance.
Moreover, the system has been tested in a real environment during an operational test. This test has underlined the complexity of operating in the real world (particularly true in the case of an active port, as it was the case of our test in Livorno). Nevertheless, quantitative metrics have been measured, that have confirmed the expectations in terms of KPIs.

Technical Impact Expected	How to measure the impact
Passive radar on board UAV	Laboratory tests for hardware optimization; antenna characterization in controlled environment; simulation of expected performance.

The antennas, used for the PR system, were examined with the radiation patterns being measured in a controlled environment of the anechoic chamber at the Fraunhofer FHR campus to ensure that all specifications working as expected prior to deployment out at the field. Moreover, the detection performance of the system was also studied based on the Matlab simulation for scenario where the final operational test took place at the Port of Livorno together with the PRN. To demonstrate the extended coverages, the PR system was stationed at different locations near the illuminators in the simulation. The detection maps were produced and showed the area where target is likely detected. The detection map of the PR can detect targets in the area of the PRN plus the additional area to the south. Additionally, the radar operates in fact out in fields at real environment so it must be tested outside the lab. Therefore, various field trials were conducted to test the radar in open environments. For technical impact, various simulations were implemented and the system was tested both in and outside the lab to ensure the functionalities are working as expected.

Technical Impact Expected	How to measure the impact
Improved automatic threat recognition, including marine pollution and moving targets	Measure, accuracy and efficiency of automatic recognition

Concerning the marine pollution detection, the deployed service has been extensively tested in terms of detection accuracy. The service as part of the 1st prototype targets in incorporating an automatic approach of oil detection over sea surface and can be utilized to substitute coast guard activities for these events to confirm the pollution and estimate the dispersion. The service should be delivered with a TRL7 meaning that its capability in identifying oil slicks has been showcased while its accuracy was validated under real conditions. Nonetheless, the detection accuracy during the 1st demonstration has been estimated only via visual data as the substituted substance of oil, rhodamine, could not be detected by a SAR sensor.
Concerning the visual object detector and tracker, the service targeted in incorporating and enhanced and highly efficient model that can process visual data and extract semantic knowledge. The incorporated model fed higher layers of integration to estimate either additional information or present the detection outcomes to the operator. Multiple tests have been performed both offline during the frequent integration tests and online during the execution of the two (2nd and 3rd) relevant demonstrations. Thus, the overall performance has been validated multiple times and under diverse conditions.

Technical Impact Expected	How to measure the impact
Innovative UxV re-configuration strategies	Overall (UGV+UAV) endurance in stand-by; Overall (UGV+UAV) range; Total attainable time of flight; Number of UAV re-charges possible from UGV

In order to cope with more complex operational scenarios, a combination of two vehicles is made possible. Specifically, an unmanned ground vehicle carrying i) a UAV and ii) a portable charging station is provided, which make possible to overcome many practical issues and acquire a significant tactical advantage. While the coptered UAVs provide a great tool to collect information on a region of interest, they are significantly limited by i) their operational duration and ii) their operational range. The solution provided in the ROBORDER system allows the UGV to transport the UAV to any desired distance in order to reach the area of interest and after that operate as a portable GCS, overcoming this way the issue of the maximum possible operational range. In addition to that, if the mission's objective is not fulfilled when the battery level of the UAVs gets low, it can return to the moving base, recharge and continue the operation after that. The mission planning tools of the ROBORDER system (Mission Editor and ARTC module) allow the standalone operation of both vehicles, but also the cooperative operation, in order to better fulfill the mission's objectives and acquire complete situational awareness.

Technical Impact Expected	How to measure the impact
Sensors and platforms adapted to extreme weather	Laboratory tests for endured temperatures and mechanical (shock and strain) resistance; In operation assessment of resistance to sun, rain and wind

Within the technical impact of adaptation of sensors and platforms to extreme weather conditions a new autonomous Unmanned Ground Vehicle was created taking an existing general-purpose all-terrain electric vehicle. This UGV was equipped with a set of sensors and actuators that allowed the vehicle to operate in variable weather conditions, preventing the ingress of water and dust in the inner and most sensitive parts of the UGV. Temperature is controlled by a Peltier-based cooling system, which allows cooling the inner parts of the UGV without any openings. UGV was tested during the second demonstration of the project, where UGV was operated until an issue with the brakes system, unrelated to the adaptation to extreme weather conditions, rendered the vehicle inoperable.

Technical Impact Expected	How to measure the impact
Contribution to the detection and identification of cyber physical attacks against border surveillance	Improved detection accuracy and latency compared to state-of-the-art approaches

systems	

To achieve the expected technical impact and contribute towards the detection and identification of cyber physical attacks against border surveillance systems, an intrusion detection and classification module (entitled IDCM) was developed within T3.4 "Detection and classification of cyber and cyber-physical attacks". All developments related to this task were reported in the deliverable D3.2 "Intrusion and illegal communications detection".
To measure IDCM's impact towards improving the detection accuracy and latency compared to state-of-the-art approaches, the module has been tested during the operational test PUC2.1 "Detecting Jamming Attacks" that was conducted in the context of the 2nd demonstration. The analysis of the obtained results, including the module's detection accuracy against jamming attacks, was reported in D6.8 "Final Evaluation reports".

Technical Impact Expected	How to measure the impact
Network communications architecture for heterogeneous UxV teams supporting re-configurability and different types of operation scenarios	End-to-end data throughput and delay, Route acquisition time, Percentage out-of-order delivery, Efficiency, Bandwidth allocation, Reaction to topological changes and traffic demands

Following the updated architecture and its implementation onto the final prototype, network communications were not relied on cloud-based solutions as this feature was also rejected by the end-use requirements for delivering a secure and locally deployed system. Network performance has been measured and validated before incorporating the corresponding equipment for safety measures. Therefore, additional network related details are provided in D5.5. "*Final integrated ROBORDER system*" [RESTREINT UE/EU RESTRICTED]. It should be highlighted that the network infrastructure that was deployed during the demonstration events was the exact same meaning that its sufficient performance was established under different scenarios (including the availability of the required assets).

5. Conclusions

The deliverable is presenting a recap of the entire ROBORDER project, of its usefulness, readiness and the achievements that were made through it. The ROBORDER platform aims at developing and demonstrating a fully-functional autonomous border surveillance system with unmanned mobile robots including aerial, water surface, underwater and ground vehicles (UAV1, USV, UUV and UGV), capable of functioning both as standalone and in swarms, which incorporate multimodal sensors as part of an interoperable network. By categorizing the objectives of the project to innovation objectives, user-oriented objectives and impact-making objectives, their efficiency and implementation is assessed, showing the progress made and successful completion of the project.

The Data Management Plan that was followed throughout the project was presented with some added features since the last report of it, based on the experiences of the involved partners and the lessons learnt. In addition, the results of the evaluation show that the objectives have been accomplished to the highest expectations and the targeted TRLs have been reached, highlighting the consistency of the project. All deliverables were submitted according to the schedule made and the respective milestones. The risk inventory kept during the lifetime of the project guaranteed the effective responsiveness and mitigation actions in case some of the predefined risk appeared.

The WP1 specified the requirements of the targeted user with respect to the proposed surveillance platform, defining the use cases, scenarios and concept of operation. In the WP2, the technologies that empowered the ROBORDER platform were established in terms of sensors, carriers and communication solutions whereas in the WP3 the detection and identification of illegal activities, cyberattacks and the enhancement of recognition capabilities were performed. The WP4 designed and developed frameworks that comprised part of the highest implementation layer, incorporating a simple and intuitive framework for operating and commanding the Unmanned Assets. An effective coordination between the technical partners has been implemented, in the framework of WP5, in order to integrate all modules in the Final ROBORDER system, aiming at designing and implementing a technical architecture, based on the user requirements. WP6 that was responsible of evaluating the developed platform and train the border authorities and LEAs for using it, was fulfilled by the data collected during the live events, that were used to compute the KPIs defined, supporting the quantitative and qualitative evaluation of the ROBORDER platform. Moreover, the market awareness targeted by WP7, was achieved with collective effort that has been focused on the planning of dissemination, analysing standardization and collaborations, developing communication materials and channels, conducting market analysis, creating business models and plans for exploitation and sustainability of project results. The last part of the self-assessment section, focused on WP8, WP9 that displayed the actions that led to the effective management of the project's time and budget, the coordination of activities and the compliance with the project's Ethics Requirements, the European Union's Guidelines as well as with the General Data Protection Regulation (GDPR).

To conclude, the impact of the ROBORDER system pointed out its contribution to the livelihood of future generations and its footprint on economy, technology and society. The activities described in the report led to the successful completion of the project's technological and management objectives.

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