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MID-TERM REVIEW AND PROGRESS REPORT

ROBORDER
740593

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This deliverable summarizes: (i) the ROBORDER objectives; (ii) a summary of the project results achieved during the first period.

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Executive Summary

Deliverable D5.3 summarizes several aspects of the project with respect to its 1st half. In that sense, the document starts with the project objectives and the current status of these. In addition to it, a project overview is provided in terms of the effort and risk register. Finally, a detailed report of the work carried out in all WPs of the project is presented, alongside with specific WP risks that were identified so far by the consortium.

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Table 1 – List of acronyms

Acronym	Meaning
AIS	Automatic Identification System
ANAC	National Institute of Civil Aviation of Portugal
API	Application Program Interface
AR	Augmented Reality
ASTM	American Society for Testing and Materials
BEMD	Bidimensional Empirical Mode Decomposition
BRLOS	Beyond Radio Line Of Sight
CA	Consortium Agreement
CAA-HU	Hungarian Civil Aviation Authority
CAN	Customer Access Node
CIRAM	Common Integrated Risk Analysis Model
CNN	Convolutional Neural Network
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CPRN	COASTAL Photonic Radar Network
DoA	Description of Action
DT	Development Tools
EC	European Commission
EEA	External Ethical Advisor
EMSA	European Maritime Safety Agency
ESA	European Space Agency
EU	European Union
FABEMD	Fast and Adaptive Bidimensional Empirical Mode Decomposition
FEM	Finite-Element Modelling
GA	Grant Agreement
GCS	Grounds Communication Systems
GDACS	Global Disaster Alert and Coordination System
GUI	Graphic User Interface
HCAA-ΥΠΑ	Hellenic Civil Aviation Authority
HOG-HOF	Histograms of Oriented Gradients - Histogram of Optical Flow
HTTP	Hyper Text Transfer Protocol
IA	Innovation Action
IDCM	Intrusion Detection and Classification Module
IEEE	Institute of Electrical and Electronics Engineers
IM	Innovation Manager
IMO	Impact-Making Objective
IO	Innovation Objective
IoT	Internet of Things
IR	Infrared
ITG	Integrated Testing
JAUS	Joint Architecture for Unmanned Systems
JSON	JavaScript Object Notation
KCF	Kernelized Correlation Filters
KPI	Key Performance Indicator
LIDAR	Light Detection and Ranging
MDCS	Multi Domain Control Station
MDL	Mission Description Language
MIMO	Multiple-Input and Multiple-Output
MONiCA	MONonitoring and Control Application
MS	Milestone
NATO	North Atlantic Treaty Organization

Acronym	Meaning
OBDH	On-Board Data Handling
OWL	Ontology Language
PD	Probability of Detection
PR	Passive Radar
PSO	Particle Swarm Optimization
PUC	Pilot Use Case
RDF	Resource Description Framework
RF	Radio Frequency
RGBD	Red Green Blue Depth
RLOS	Radio Line Of Sight
ROS	Review Of System
RPAS	Remotely Piloted Air System
SAR	Synthetic Aperture Radar
SDR	Software Defined Radio
STANAG	Standardization Agreement
STM	Scientific and Technical Manager
SYA	Systems Analysis
TCP/UDP	Transmission Control Protocol / User Datagram Protocol
TRA	Training
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UCA	Uniform Circular Array
UGV	Unmanned Ground Vehicle
UI	User Interface
UK	United Kingdom
UO	User Objective
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
UxVs	Unmanned Vehicles
VR	Virtual Reality
WP	Work Package

1 Explanation of the work carried out by the beneficiaries and overview of the progress

This Deliverable reports the current status of project objectives, alongside with the report on the technical and risk management activities performed during the first eighteen months of project ROBORDER.

1.1 Objectives

This section presents the specific objectives for project ROBORDER as described in section 1.1 of the Description of Action (DoA) and describes the work carried out towards the achievement of each objective. Each of these specific objectives is composed by several activities that were also identified in the DoA.

I. Innovation objectives (IOs)

IO1: Adaptable sensing, robotics and communication technologies for different operational and environmental needs

This objective is directly linked to WP2 (Sensing, robotics and communication technologies) and it has been partially achieved. As described in the DoA, the Innovation Action (IA) 1.1 was already accomplished through the successful deliver of D2.1 (Communication architecture report), which describes the communication architecture for the ROBORDER System – it includes: (i) a trade-off of cloud services; (ii) description of several communication protocols used by UxVs; (iii) the end-user requirements related to the communications architecture; and (iv) a description of the high-level communication architecture for the ROBORDER System. The remaining IAs for this specific objective are due M24 of the project, in that sense these IAs are not yet completed (at the time of writing – M18). The current status of some of these on-going IAs was reported in D2.2 (Performance assessment of ROBORDER configurations), which included a summary of the current status of T2.2 (Passive radar sensor on board UAVs and USVs), T2.3 (RF signal sensor on board UxVs) and T2.4 (Sensors adaptability). In addition to it, the status of these tasks, alongside with T2.5 (Re-configuration of agents and carrier solution) and T2.6 (Photonic-based radars) is provided in Section 1.3.2 of this report which covers the entire work carried out in WP2.

IO2: Detection and identification of border-related threats

This objective is directly linked to WP3 (Detection and identification of border-related threats) and it has not been yet achieved. As described in the DoA, the IAs for IO2 are related to the work carried out in WP3 but, since this WP will be on-going until M24, it is expected that these activities have not been yet accomplished. Nevertheless, the current status of these activities is provided in Section 1.3.3 of this report which describes the work carried out in WP3.

IO3: Tele-operation of autonomous agents through a 3D user interface and decision support

This objective is directly linked to WP4 (Command and control unit functionalities) and it has not been yet achieved. As mentioned in the DoA, the IAs for IO3 are related to the work performed in WP3 however, since this WP will be on-going until M24, it is expected that these activities have not been yet completed. Nevertheless, the current status of these activities is provided in Section 1.3.4 of this report which describes the work carried out in WP4.

IO4: ROBORDER platform development and integration

This objective is directly linked to WP5 (Integration of ROBORDER platform for the remote assessment of border threats) and has been partially achieved. As indicated in the DoA, this IO comprises both the development and integration activities for the ROBORDER System. In this sense, the initial part of this objective was achieved through the successful deliver of D5.1 (Technological Roadmap), D5.2 (Technical Requirements and operational architecture) and D5.3 (1st Integrated ROBORDER System). From D5.1, the strategy for the development of ROBORDER technological roadmap was provided alongside with the catalogue of products and modules that will be employed within the whole system and, ultimately, it presents the time plan for the overall project developments with respect to the WPs and Milestones previously defined. Moreover, D5.2 provides the first assessment of requirements performed by the end-users alongside with the technical requirements (divided into functional and non-functional requirements); in addition to it, it presents a trade-off analysis on different architecture models that was the baseline for the adoption of NATO MDCS as the main driver for the development of ROBORDER System; finally, it describes the operational, software and physical architectures for the ROBORDER system, as well as the approach for the definition of the data model and the interfaces to be adopted in order to guarantee interoperability for the whole system. Regarding D5.3, it reports the 1st Prototype that was presented and already tested, which enabled the consortium to validate the ROBORDER System architecture and its communications between the System and platforms (UxVs) and services/modules. Since WP5 is expected to be on-going until M34, it is expected that further versions of the ROBORDER System (2nd and final integrated versions of the ROBORDER System) will be delivered and, in that sense, it is expectable that this objective was not yet fully accomplished. The current status of all activities of WP5 is provided in Section 1.3.5 of this report which describes the work performed in WP5.

II. User-oriented objectives (UOs)

UO1: User requirements definition, end-user evaluation and validation

This objective is directly linked to WP1 (User requirements and pilot use cases) and WP6 (Demonstration and evaluation) and has been partially achieved. As mentioned in the DoA, this User-oriented Objective (UO) is the main input for the aforementioned IOs, in order to guarantee that the user goals and requirements are taken into account for the specific technological developments of the project. A methodology has been developed within the activities of WP6. This methodology aims to evaluate and validate the performances of the ROBORDER platform against end-users' needs. An action plan has been developed to ensure ROBORDER will be tested in each Pilot Use Case required by the end-users. At this stage, to support the evaluation, the test-bed simulation for ROBORDER Project has been designed and entered the first stages of implementation. Moreover, at the time of writing of this report, D1.1 (Draft of Concept of Operation, Use Cases and Requirements) was delivered and it demonstrates that, at least, part of the activities envisioned to ensure the achievement of this goal were concluded and will be used as the baseline for the remaining ones. Although that, WP1 will be on-going until M28 – in that sense, it is expected that this goal is not yet totally achieved. The current status of the activities of WP1 is provided in Section 1.3.1 of this report which describes the work performed in WP1.

III. Impact-making objectives (IMOs)

IMO1: Dissemination and collaboration

This objective is directly linked to WP7 (Dissemination and exploitation) and has been partially achieved. At the time of this report, several activities related with the dissemination of the project results were performed, thus contributing to the successful achievement of this Impact-Making Objective (IMO), in terms of dissemination. In respect to the collaboration with other projects, as reported in D7.4 (Mid-Project Dissemination Reports), the consortium is aware of the importance of such initiatives; in that sense, a joint workshop between other consortiums working in security projects (e.g. CAMELOT and MARISA) is foreseen to be scheduled during the second half of the project. Nevertheless, the tasks related with this specific objective will be running until M36 of the project, thus it is expected that at the time of this report, this objective was not yet fully achieved. The current status of these dissemination actions is provided in Section 1.3.7.

IMO2: Exploitation and sustainability model
This objective is directly linked with WP7 (Dissemination and exploitation) and has been partially achieved. So far, D7.3 (Market Analysis) was already delivered which includes a market analysis for existing solutions, and it directly contributes to the successful achievement of this IMO. With respect to the exploitation and sustainability model, since the WP7 will be on-going until M36, activities to tackle these aspects are only envisioned to be finished at the end of the project. In that sense, it was expected that, at the time of writing of this report (M18), that this IMO wouldn't be already, at least, fully achieved.

1.2 Project Overview

Project ROBORDER started in May 2017 and is expected to end in April 2020 (36-month project). Having been ongoing for 18 months, the consortium has already achieved some of the desired results. Nevertheless, there is still much work to be done to reach the final version of the ROBORDER system with all its capacities and functionalities.
Figure 1 presents the Gantt chart for project ROBORDER (the current progress is identified by the grey area).

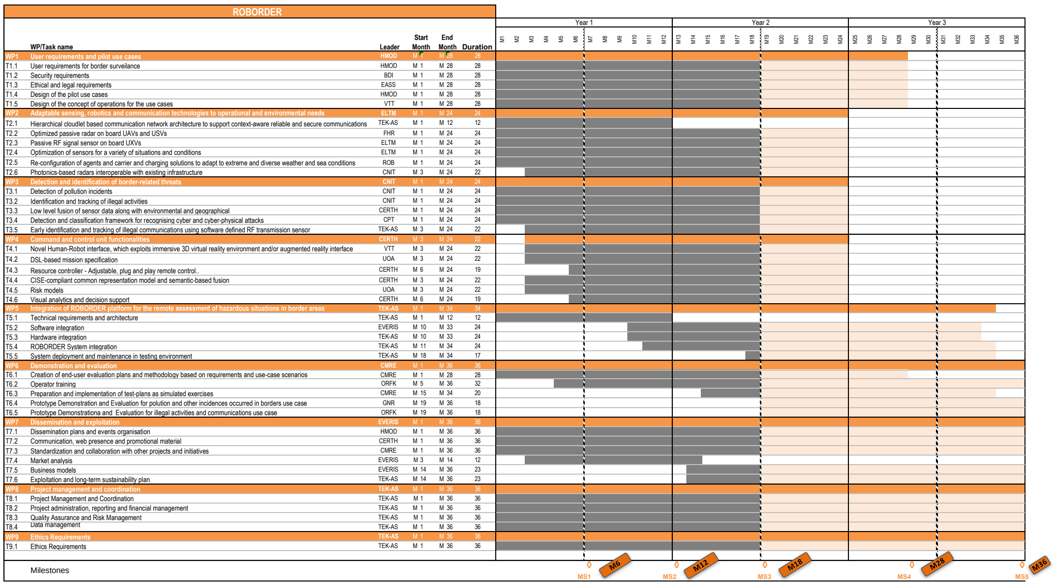

Figure 1 – ROBORDER Gantt chart with progress (enlarged version in Section 2 - Annexes)

From the above diagram, it is possible to notice that ROBORDER project already achieved the first three Milestones. The achievement of these three MileStones indicate that ROBORDER has already concluded the initial requirements assessment from both the end-users perspective (WP1) and the technical partners' view (WP5), as well as that the high level architecture has been successfully defined (WP5), including the communications architecture (WP2). Moreover, the consortium is now pursuing the necessary developments to achieve such requirements (WP2 to WP4), in close cooperation with WP6 that already delivered several documents covering the envisioned tests and evaluation actions to be performed on the ROBORDER System. Ultimately, activities on dissemination of the project results have been ongoing, and efforts to disseminate ROBORDER in several industry-specific events have been undertaken. These efforts are described in section 1.3.7: WP7.

Table 2 below depicts the list of milestones updated with an explanation on the current status of the past milestones. It is clear from the list of milestones that three out of the five project milestones have already been achieved at the time of writing of this Periodic Technical Report.

No.	Milestone Title	WP	Leader	Due Date	Means of Verification	Status	Explanation on Status
MS1	Project setup and platform development roadmap	1 5 6 7 8	TEK-AS	10/2017	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.	**Achieved**	The kick-off meeting was organized by TEKEVER and was held in Lisbon on May 16th – 17th, 2017. All partners attended with the exception of those that, due to more pressing commitments couldn't be present. The Project Officer was also present. In addition to it, MS1 was verified as achieved through the successful delivery of: D5.1, D6.1, D7.1, D8.1, D8.2, D9.1, D9.2 and D9.3, as well as the initial draft version of D1.1.
MS2	Operational Prototype	2 3 5	TEK-AS	04/2018	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, D5.2, D9.4, D9.5, D9.6.	**Achieved**	This milestone was successfully achieved through the delivery of D2.1, D2.2, D5.2, D9.4, D9.5 and D9.6. Moreover, initial draft versions of D3.1 and D3.2 started to be prepared, and the final versions of these are expected to be delivered in time (i.e. M24 as stated in the GA).

No.	Milestone Title	WP	Leader	Due Date	Means of Verification	Status	Explanation on Status
MS3	1st Prototype	1 4 5 6 7 8	TEK-AS	10/2018	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 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, D5.3, D6.2, D6.3, D6.6, D7.3, D7.4 and D8.3.	**Achieved**	MS3 was successfully achieved, thus guaranteeing a successful first development cycle of the project. This can be verified through the successful delivery of D1.1, D5.3, D6.2, D6.3, D6.6, D7.3, D7.4 and D8.3.
MS4	2nd Prototype	1 2 3 4 5 6 7 8	TEK-AS	08/2019	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, ii) Adaptability solutions for robotic platforms, iii) Event and Activity Detection and Recognition, iv) Intrusion and illegal communications detection, v) UxVs tele- operation framework and interface and vi) Visual analytics	Open	N/A

No.	Milestone Title	WP	Leader	Due Date	Means of Verification	Status	Explanation on Status
					and decision support tools based on risk models and reasoning methods. It will also include i) Business Model, ii) Self-assessment and data management plan v2, iii) the second evaluation report, iv) the M&S based Test Bed Demonstration and v) the third cycle of the Concept of Operation, Use Cases and Requirements. Deliverables contributing to MS4: D1.1.3, D2.3, D2.4, D3.1.2, D3.2.2, D4.1.2, D4.2.2, D5.3.2, D6.3.2, D6.4.2, D7.5, D8.4.		
MS5	Final System	5 6 7 8	TEK-AS	04/2020	MS5 marks the successful completation 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. Deliverables contributing to MS5: D5.3.3, D6.3.3, D6.4.3, D6.5, D7.4.2, D7.6, D7.7, D8.5	Open	N/A

Table 2 – List of milestones

Table 3, sorted according to due date, presents the status of ROBORDER from a delivery standpoint, i.e. in terms of the amount of deliverables submitted and overdue

No.	Deliverable Name	WP	Leader	Type[1]	Diss. Level[2]	Due Date	Status
D7.1	Dissemination Plan	7	HMOD	R	PU	07/2017	Submitted
D7.2	ROBORDER Website and communication material	7	CERTH	R	PU	07/2017	Submitted
D8.1	Project management and quality assurance plan	8	TEK-AS	R	PU	07/2017	Submitted
D9.3	POPD – Requirements No. 10	9	TEK-AS	ETHICS	CO	07/2017	Submitted
D5.1	Technological Roadmap	5	TEK-AS	R	RES_EU	10/2017	Submitted
D6.1	Evaluation Methodology using benchmarking	6	CMRE	R	RES_EU	10/2017	Submitted
D8.2	Self-assessment and data management plan V1	8	TEK-AS	R	PU	10/2017	Submitted
D9.4	OEI – Requirements No. 14	9	TEK-AS	ETHICS	CO	10/2017	Submitted
D2.1	Communication architecture report	2	TEK-AS	R	RES_EU	04/2018	Submitted
D2.2	Performance assessment of ROBORDER configurations	2	ELTM	R	RES_EU	04/2018	Submitted
D5.2	Technical requirements and operational architecture	5	TEK-AS	R	RES_EU	04/2018	Submitted
D9.1	H – Requirements No. 5	9	TEK-AS	ETHICS	CO	04/2018	Submitted
D9.2	POPD – Requirements No. 6	9	TEK-AS	ETHICS	CO	04/2018	Submitted
D9.5	DU – Requirements No. 15	9	TEK-AS	ETHICS	CO	04/2018	Submitted
D7.3	Market Analysis	7	EVERIS	R	PU	06/2018	Submitted
D6.2	Action plan for PUC	6	CMRE	R	PU	07/2018	Submitted
D5.3	First Integrated ROBORDER System	5	TEK-AS	R	RES_EU	10/2018	Submitted
D9.6	GEN – Requirements No. 19	9	TEK-AS	R	CO	10/2018	Submitted
D1.1	Draft of Concept of Operation, Use Cases and Requirements	1	HMOD	R	RES_EU	10/2018	Submitted
D6.3	First M&S based Test Bed Demonstration	6	CMRE	R	RES_EU	10/2018	Submitted
D6.6	First Evaluation report	6	CMRE	R	RES_EU	10/2018	Submitted
D7.4	Mid-Project Dissemination Reports	7	HMOD	R	PU	10/2018	Submitted
D8.3	Mid-term review and progress report	8	TEK-AS	R	PU	10/2018	Submitted

[1] Nature of the deliverable:
- **R** = Document, report (excluding the periodic and final reports)
- **DEM** = Demonstrator, pilot, prototype, plan designs
- **DEC** = Websites, patents filing, press and media actions, videos, etc.
- **ETHICS** = Ethical documents, reports, permits, etc.
- **OTHER** = Software, technical diagram, etc.

[2] Dissemination level:
- **PU** = Public
- **CO** = Confidential
- **RES_EU** = EU Restricted

No.	Deliverable Name	WP	Leader	Type[1]	Diss. Level[2]	Due Date	Status
D2.3	Final Sensors Implementations	2	ETLM	R	RES_EU	04/2019	-
D2.4	Adaptability solutions for robotic platforms	2	ROB	R	RES_EU	04/2019	-
D3.1	Event and activity detection and recognition	3	CERTH	R	RES_EU	04/2019	-
D3.2	Intrusion and illegal communications detection	3	CPT	R	RES_EU	04/2019	-
D4.1	UxVs tele-operation framework and interface	4	CERTH	R	RES_EU	04/2019	-
D4.2	Visual analytics and decision support tools based on risk models and reasoning methods	4	CERTH	R	RES_EU	04/2019	-
D7.6	Business Model	7	EVERIS	R	PU	04/2019	-
D8.4	Self-assessment and data management plan V2	8	TEK-AS	R	PU	04/2019	-
D5.4	Second integrated ROBORDER system	5	TEK-AS	DEM	RES_EU	06/2019	-
D6.4	Second M&S based Test Bed Demonstration	6	CMRE	R	RES_EU	06/2019	-
D1.2	Final Concept of Operation, Use Cases and Requirements	1	HMOD	R	RES_EU	08/2019	-
D6.7	Second Evaluation report	6	CMRE	R	RES_EU	08/2019	-
D5.5	Final integrated ROBORDER system	5	TEK-AS	R	RES_EU	02/2020	-
D6.5	Final M&S based Test Bed Demonstration	6	CMRE	R	RES_EU	02/2020	-
D6.8	Final Evaluation reports	6	CMRE	R	RES_EU	04/2020	-
D6.9	Operator Training Manual	6	ORFK	R	RES_EU	04/2020	-
D7.5	Final Dissemination Reports	7	HMOD	R	PU	04/2020	-
D7.7	Report on Standards and Collaborations	7	CMRE	R	PU	04/2020	-
D7.8	Exploitation plan and sustainability model	7	EVERIS	R	PU	04/2020	-
D8.5	Public final activity report	8	TEK-AS	R	PU	04/2020	-

Table 3 – ROBORDER deliverable register

As can be seen by the deliverable register, ROBORDER is up to date in terms of reporting.

1.2.1 Risk Management

Under the scope of WP8 (Project Management), the management of the risks related to the project is performed (as defined in Section 3.2.3 of Annex B of DoA). The following table contains the risk register until the date of this report.

No.	Description	Lead	WP	Risk mitigation measures	SoP-M[3]	SoP-MA[4]	Status/Comments
1	Violation of data privacy	TEK-AS	1 5 6	ROBORDER will conform to all necessary procedures to safeguard privacy requirements (Task 1.3). Participation will be voluntary, with a clear document on how private information will be used during the project and private data will be anonymised according to the ethical protocols (details in section 5.1 of Annex B of DoA).	No	None	Open
2	Failure of scientific integration	TEK-AS	5	The consortium includes partners with excellent capabilities in cross-discipline collaboration. Clear inter-play between WPs and tasks and appropriate monitoring practices have been designed in order to promote integration from the very beginning of the project. If some research modules cannot be integrated, dedicated small demonstrators will be provided.	No	None	The impact from this risk has been significantly reduced through the validation of architecture and communications between the system and (i) platforms (UxVs) and (ii) services.
3	The planned approach is not successful because of new technical developments that render it obsolete.	TEK-AS	5	The "plug-n-play" nature of the ROBORDER platform enables the easy and straightforward interfacing and integration of new technologies that may be available during the project lifetime.	No	None	N/A
4	Difficulties recruiting sufficient numbers of users for PUCs by the consortium	CMRE	6	We will proceed with the recruitment of users at the institutions of the members of the user group.	No	None	No longer relevant
5	Time for development of the prototype and its validation is	CMRE	6	Change prioritisation of developed tasks. Project checkpoints will monitor and detect problems early and take corrective action.	No	None	The consortium consider that the development of the prototype will

[3] *SoP-M – State of the Play Materialization*
[4] *SoP-MA – State of the Play Mitigations Applied*

No.	Description	Lead	WP	Risk mitigation measures	SoP-M[3]	SoP-MA[4]	Status/Comments
	underestimated			Successive project approach with 3 evaluation cycles allows for smooth re-scoping to mitigate against delayed delivery of platform.			possibly take more time than the estimated at the proposal stage due to the implementation of the Data Model.
6	Partner drops out of the project	TEK-AS	8	We will target a direct replacement with a partner of similar expertise. The good reputation of all partners of the consortium and their complementary expertise will facilitate this task.	No	None	TEK has been declared a defaulting party by the Consortium and has received pre-notification of suspension of payments to the company.
7	As a direct impact of the EU referendum result (Brexit), the eligibility of UK entities to receive EU research funding beyond 2018 are currently unknown. Should the UK's access to funding be revoked during the projects funded period, this may pose an immediate impact on UK entities ability to fulfil their commitments to the project.	TEK-AS	8	1) The UK Government announced on Saturday (13 August) that it will underwrite funding for approved Horizon 2020 projects applied for before the UK leaves the European Union. The guarantee applies to funding applied for before Brexit, and the Government will underwrite the payment of such awards, even when specific projects continue beyond the UK's departure from the EU. Details of the announcement can be found here: http://www.hefce.ac.uk/news/newsarchive/2016/Name,109430,en.html 2) Sheffield Hallam University's Vice Chancellor has also committed to funding the fulfilment of CENTRIC's obligations using its own resources, should there be any shortfall in funding due to ineligibility after Brexit. A formal letter containing confirmation of this commitment is attached in Annex B of parts 4-6.	No	None	Open. So far, this risk has not been verified; the project coordinator will keep monitoring this point during the 2nd half of the project.
8	Ill implemented	TEK-AS	5	Clear definition of interfaces and provision of	No	None	This risk wasn't verified.

No.	Description	Lead	WP	Risk mitigation measures	SoP-M[3]	SoP-MA[4]	Status/Comments
	interoperability interfaces may limit the impact of ROBORDER			APIs to existing systems will be fundamental in preventing this risk. (addressed in T5.1)			It is no longer applicable.
9	Lack of resources to carry out demos will limit the impact and acceptance of ROBORDER	CMRE	6	A plan for demonstrations has been setup and will be detailed during the activities of tasks T6.4 and T6.5. The responsible partners and end-users have planned resources to make them possible according to their best expertise. Both technical partners and practitioners have made provisions for making assets available (existing and new ones such as UGV, UUV, USV and UAVs). If for some reason, some practitioners cannot commit means to tests and demos, the MB will propose a shift of effort and budget to another end-user to carry out the demo. The demos will happen in the second half of the project, allowing sufficient time to plan and commit assets.	No	None	Open
10	Lack of testing all combinations of modules (possibly at the same time) may pass the impression of an incomplete technical validation	CMRE	6	Indeed it will be impossible to test all combinations merely because some functionalities are not made to work together. By giving priority to user driven workflows and testing different user cases and scenarios prepared by end-users, the consortium is confident the practitioner and scientific communities will be satisfied.	No	None	Open
11	Delays in the distribution of funds may result in partners stopping their technical contributions and hence in delays to the project execution	TEK-AS	8	Possible mitigation strategies include: • Change of coordination and subsequent application of sanctions to the coordinator by the consortium (following the CA rules); • Application of sanctions to the coordinator	Yes	The coordinator has been voted in breach of its obligations by the consortium. The consortium voted for replacing TEK in the	Open

No.	Description	Lead	WP	Risk mitigation measures	SoP-M[3]	SoP-MA[4]	Status/Comments
				by the EC (including possible termination); • Request project extension to the Commission to ensure adequate project execution once financial issue is resolved.		role of coordinator. TEK is in the process of proposing a timeline to conclude the distribution of funding to affected partner. This risk will be closed as soon as funding is distributed to all partners.	
12	Lack of partners' contributions to some of the reporting activities	TEK-AS	1 5 6 7	Possible mitigation strategies include: • Work Package leaders to organize more frequent virtual meetings to assess the status of participation of each partner for the specific WP and/or deliverable. • Responsible partner shall prepare a timeplan in the beginning of the preparation of deliverables, and keep the record of the contributions status per involved partner. In that way, it will be easier for the responsible to assess what's missing in a manageable time.	No	None	Open

Table 4 – Risk Register

1.3 Explanation of the work carried per WP

The current section will describe the work performed under each work package in the first fifteen months of project ROBORDER.

1.3.1 Work Package 1

Work package number	WP1	**Start month**	1	**End month**	28
Work package title	User requirements and pilot use cases				
Lead partner	HMOD				
Contributing partners	TEK-AS, CERTH, EASS, VTT, PSNI, GNR, CMRE, ORFK, SPP, CENTRIC, APL, BDI, MJ, RBP				

The key objective of WP1 is to study and specify the requirements of the targeted users with respect to the proposed surveillance platform, analysing and turning them into specifications. Based on this analysis, it will define and deliver a number of representative use cases, scenarios and concept of operations (ConOps) to exemplify the novelties of the ROBORDER system. Moreover, WP1 considers all security, ethical and legal requirements of the envisioned system.

The following section includes the advancements that have been performed for the corresponding WP1 tasks. The analysis is provided per task below.

T1.1: Analysis of user requirements and operational aspects (M1-28) & T1.4: Design of the pilot use cases (M1-28), Lead: HMOD

ROBORDER research program Grant Agreement has been meticulously studied for HMOD to orchestrate the most appropriate course of action to deliver products that meet the requirements. For that purpose, a project team has been established and on October 2017 a draft user operational requirements document was submitted. Easy to use templates were created and distributed to the relevant participants to facilitate end-user inputs collection. Nominated personnel participated in the progress review meetings and updated ROBORDER consortium on the inputs collection status. Additionally, HMOD project team organized 2 teleconferences to better synchronize the effort and coordinate actions for timely product delivery. The project team developed the D1.1 deliverable titled “Draft of Concept of Operation, Use Cases and Requirements”. This document encloses end-user requirements and the relevant key performance indicators to evaluate if those requirements are met and how well the system performs in key areas of operation. It also contains detailed high level, primary and secondary use cases as well as scenarios where the system can be tested and evaluated. Furthermore, the deliverable includes the system concept of operations within the framework specified by the Grant Agreement and adapted by the end-users projected demands. On October 2018, D1.1 deliverable has been submitted, in time, for peer review.

T1.2: Analysis of security requirements (M1-28), Lead: BDI

The security requirements were studied by state-of-the-art, current technology on the market, questionnaire sent to end-users, and best practices in the area. Results are included in D1.1 and additionally the security requirements are monitored during the development and evaluation phases of the project. If it is identified that some of the main requirements are not met WP leaders are informed and mitigation actions will be made. The analysis of the survey shows that three main aspects of the information system security need to be covered in the project, namely: confidentiality, integrity and availability. Also it is clearly shown that communication security between the elements of the system is preferable to be achieved by software based encryption with existing (approved) algorithms. Additionally, all end-users required multi level access control to the system and elements.

T1.3: Analysis of ethical and legal requirements (M1-28), Lead: ORFK

Ethical and legal requirements were investigated by desktop research, survey among involved end-users on national RPAS rules and by gap analysis. Results are included into D1.1. The results cover privacy and data protection issues, ethorobotics (may a robot arrest me?) as well as aviation security rules and operator training requirements. The main aim of the task was twofold: first to identify requirements related to the execution of the project, second to provide parameters for a future, fully authorized system.

T1.5: Design of concept of operations for use cases (M1-28), Lead: VTT

VTT made first an extensive review of Concept of Operations (ConOps) methods, standards and example cases from different domains. Based on the ConOps methods and the ROBORDER project goals, the initial ConOps for ROBORDER was defined in 2017 (see Figure 2). The initial ConOps diagram demonstrated, at a general level, different actor co-operations and classifications in border guard domain.

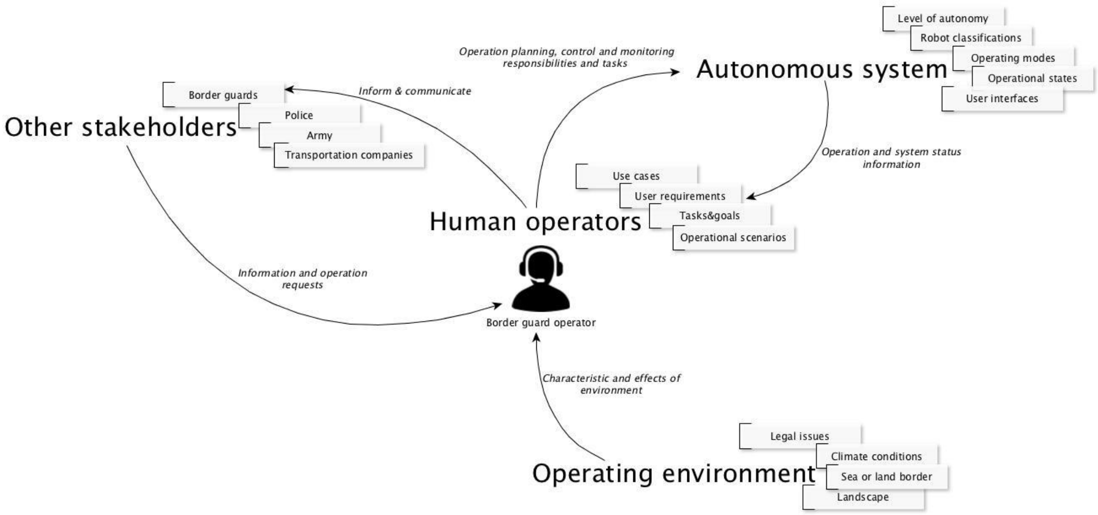

Figure 2 – Initial ROBORDER ConOps diagram

The ConOps work continued on two fronts: first, we analysed Use Cases generated by end-user partners in WP1, and, second, we planned interviews focussing on the ROBORDER Use Cases and ConOps. Seven interview sessions were executed between 6th February 2018 and 27th April 2018 with four end-user partners (Greece, Hungary, Portugal and Romania). The results are presented in more detail in the ConOps section of the Deliverable 1.1. The main results are listed in tables, which indicate outcomes of different use cases and interview topics. Based on these results, the use case -specific ROBORDER ConOps diagrams were generated (see Figure 3). The results tables and the ConOps diagrams can be utilized when defining use requirements and operational/technical features of the ROBORDER systems.

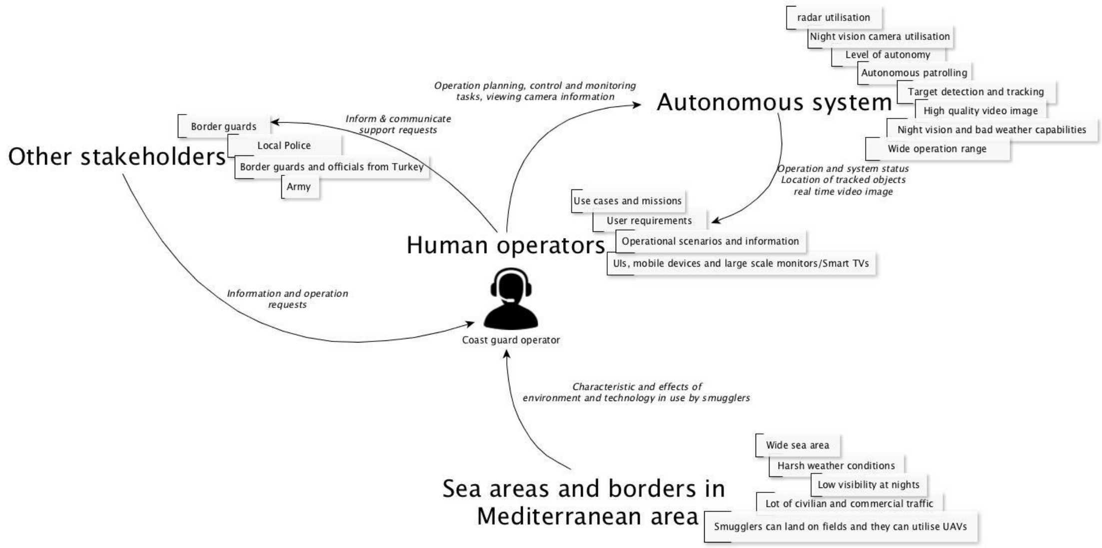

Figure 3 – One example of a ConOps diagram (sea broder supervision based on HMOD Greek use case)

1.3.1.1 WP1 Risks

This section presents the current WP1 risks.

Work Package 1 Risk	
Risk 1	Lack of participation of ROBORDER Partners in the contribution of D1.1 • Mitigation: thorough involvement of partners.
Risk 2	PUCs are not well defined – technical partners can't define proper requisites neither to design an architecture for the system that is able to answer to all the end-user necessities expressed in the current version of the PUCs. • Mitigation: (1) define some aspects of the architecture that enable the technical work to continue (e.g. data model and interfaces); (2) motivate the end-user partners to specify as much as possible the current PUCs.

Table 5 – Work Package 1 Risks

1.3.2 Work Package 2

Work package number	WP2	**Start month**	1	**End month**	24
Work package title	Sensing, robotics and communication technologies				
Lead partner	ELTM				
Contributing partners	TEK-AS, CERTH, FHR, ROB, OMST, Copting, UoA, CSEM, CNIT, CPT				

The objective Work Package 2 is to establish innovative technologies and building blocks that empower the ROBORDER platform in terms of sensors, carriers/platforms, and communication solutions. Each task covers the design and prototyping of the addressed technology, including laboratory verification of its functions.

The following section includes the advancements that have been performed for the corresponding WP2 tasks, as well as the current status of their implementation. The analysis is provided per task below.

T2.1: Cloudlet based communications (M1-12), Lead: TEK-AS

The main objective of T2.1 was to define the ROBORDER communications architecture, and this objective could be verified as accomplished through the successful submission of D2.1 (Communication architecture report). Thus, the following paragraphs summarize D2.1's content.

At the proposal stage, the consortium considered that the communications architecture could be made through the use of a cloud-service solution (internet based). In that sense, the initial step taken in T2.1 was to make a market analysis on several available cloud services, namely: (i) Mainflux open source IoT; (ii) Sofia2 IoT platform; (iii) AWS IoT; (iv) Azure IoT Hub; and (v) Watson IoT (Bluemix). Afterwards, a trade-off analysis on the previous identified solutions was performed, having in mind the following criteria: (i) Application to development; (ii) Device management; (iii) System management; (iv) Heterogeneity management; (v) Data – protocols and communication; (vi) Monitoring; (vii) Security and Authentication; (viii) Open Source; and (ix) License Price. The results from this analysis can be consulted in Table 2 of D2.1; despite Azure IoT Hub was considered as the most complete and applicable solution, the consortium considered that, although with a few additional limitations, the open-source solution Mainflux IoT was also suitable for the project needs.
Moreover, information regarding the different communication protocols in use by the asset providers was collected and also reported in Section 3 of D2.1. These communication protocols are: (i) STANAG 4586, for the case of TEKEVER's UAVs; (ii) MAVLINK, for the case of Copting's UAVs; (iii) ROS for the case of ROBOTNIK's UGVs; and (iv) IMC for the case of OceanScan's USVs/UUVs. In addition to these, JAUS and JANUS were also analysed and included in the report since these two represent good examples of standardized communication protocols (mainly applicable to, respectively, UGVs and UUVs).

Afterwards, technical partners involved in T2.1 started analysing the end-user requirements which were directly related to the communications of ROBORDER System (as reported in Section 4.2 of D2.1). From these, the most relevant requirement that was identified was the following:

- The consortium shall ensure that the ROBORDER System will be deployed in such an environment that no internet connection (i.e. external access) will be required for the system to be operated and, at the same time, to interface with both the assets' proprietary GCSs and the services to be integrated within the system itself. This requirement is, *per se,* a very important characteristic to be taken into account by the fact that it excludes some of the options considered initially to perform and manage the system communications.

Based on the above presented and the remaining requirements, the consortium idealized the high level ROBORDER communications architecture (this idealization was made in parallel with WP5, in particular with T5.1), in which internet is only considered in the case that the system requires to access external data (e.g. Bing maps service), while all the remaining communications within the system are to be made only via intranet. This high-level communications architecture was described with more detail in Section 4.3.1 of D2.1. In addition to it, the communication interfaces between ROBORDER System and (i) UxV assets and (ii) services were defined, and these are illustrated in the schemes presented below.

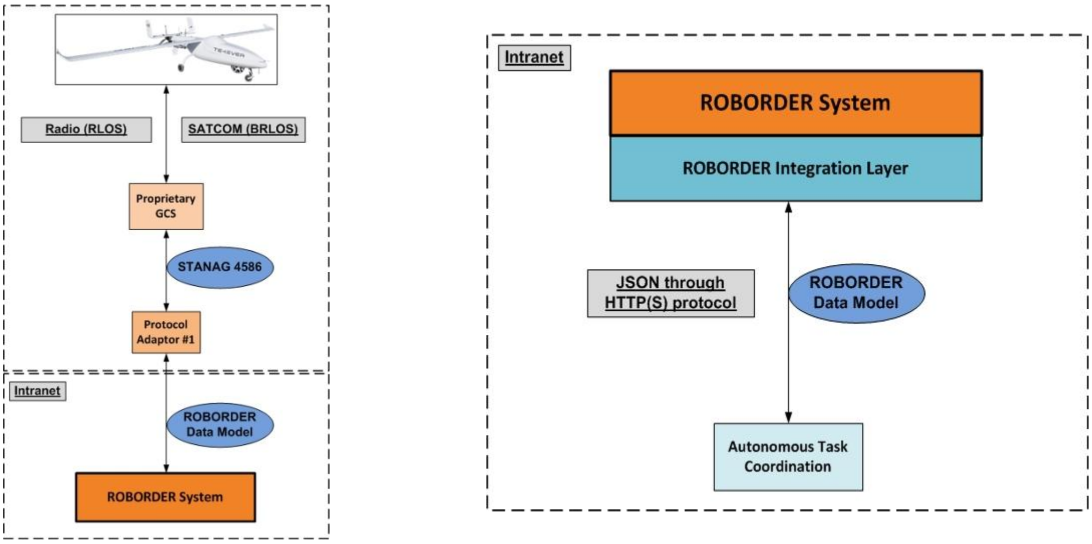

Figure 4 – ROBORDER System communication interface with UxV assets (left) and services (right)

The above schemes were used as examples of the different types of communications present within the ROBORDER system, i.e. between the ROBORDER system and (i) UxV assets or (ii) services. For the UxV assets, information is sent to the ROBORDER system from the proprietary GCSs using the proprietary communication protocols (for the case of TEK's AR5 UAV, using radio for RLOS or Satcom for BRLOS), passing through the respective protocol adaptor in order to translate these messages into the ROBORDER Data Model; the same occurs in the other way around, in which information being sent from the ROBORDER system to the UxV assets is sent in the ROBORDER Data Model (via the intranet) and will be translated into the proprietary protocol of the asset through the protocol adaptor. In the case of services, the same rationale was applied, i.e. all information being exchanged (using JSON through HTTP(S) protocol) between the ROBORDER System and the services (via the intranet) is translated into the ROBORDER data model by passing through the ROBORDER integration layer. These examples were respectively explained with more detail in Sections 4.3.2 and 4.3.3 of D2.1.

Ultimately, under this task, the consortium concluded its execution by gathering some remarks regarding the communications architecture, which were used as inputs to the conceptualization of the high level architecture for the whole system (which was under definition in WP5). These remarks were reported in Section 5 of D2.1, and are presented in the following bullets:

- Based on the assessment of end-user requirements regarding the communications of ROBORDER System, the consortium concluded that the ROBORDER System will be deployed in an environment with no internet connection, making this limitation a requirement for the system and service modules operation.
- Considering the last bullet, the consortium decided to discard the initial idea of implementing the ROBORDER System in a cloud environment (because of the dependency on an internet connection) in order to fulfil the requirements identified by the end-user partners.
- It will be based on a publisher/subscriber pattern, from which services or platforms will publish and subscribe to the information that is relevant to perform their own function and feed other utilities;

- All communications with respect to the interface between ROBORDER System and assets/services will be made using the ROBORDER Data Model.
- It was decided that each asset provider will develop the respective protocol translator module that will enable its asset to communicate with the ROBORDER System – this protocol translator will be responsible for translating the messages coming from the system to the asset (from ROBORDER Data Model to the specific communication protocol) and vice-versa.
- A to be defined middleware will be used to manage all the communications between the Mission System and Services – all the results to be published by a certain module will have to pass through this middleware and will have to follow the ROBORDER Data Model.
- Services that require data coming from other services and/or the Mission System will have to subscribe in order to obtain that input data through the 'to be defined' middleware.

T2.2: Photonics-based radars (M1-24), Lead: FHR

The main goal of T2.2, led by FHR, is to extend the radar coverage of coastal photonic radar network (CPRN) which is developed by partner CNIT. In order to achieve this goal, FHR leads the development and implementation of a Passive Radar (PR) in both UAV and USV platforms, thus enabling these to patrol the coast and/or the border of interest. This task will be on-going until M24, but the so far achieved developments were reported in Section 2 of D2.2.

One of the initial steps taken under this task was to define the configurations of both the CPRN and PR, as depicted below:

- **CPRN configurations:**
  - Passive radar system must align with the CPRN configuration, which is currently under development in T2.6 ('Photonics based radar');
  - X-band modes are currently under analysis in terms of: (i) fixed antennas; (ii) two transmitters (Tx) exploited simultaneously, and (iii) medium range coverage.
- **PR configurations:**
  - X-band receiver: two fixed horn antennas – one looking at Tx, while the other one will be looking for the area of interest.

After the definition of both configurations, the concept of operation for the interaction between the CPRN and PR was defined. The rationale of this concept of operation consists in the following: the coastal radars will be emitting signals, while the UAV platform carrying the PR onboard will be responsible of collecting the reflected signals. After the data collection, the processing will be performed onboard the UAV, and the detection outputs are intended to be sent to the ROBORDER System by making use of the communication between the asset and the system.

Moreover, the signal processing flow for the CPRN and PR was defined it is presented in Figure 5 (the description of this workflow was included in Section 2.2 of D2.2).

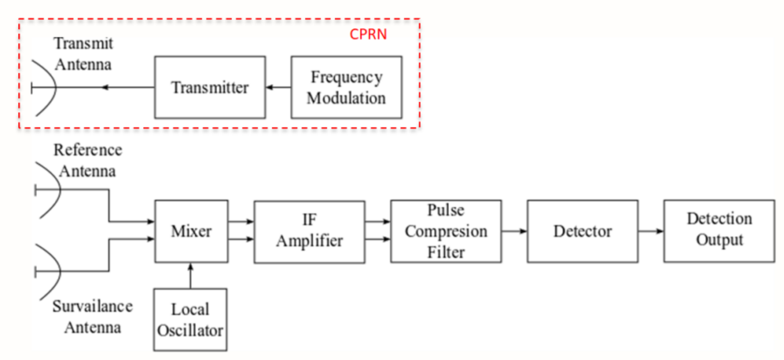

Figure 5 – Signal processing flow for the CPRN and PR

Afterwards, FHR outlined the architecture for the system (see Figure 6) combining the CPRN and PR, and started preparing the simulation of the system by using the software ‘GNURadio’.

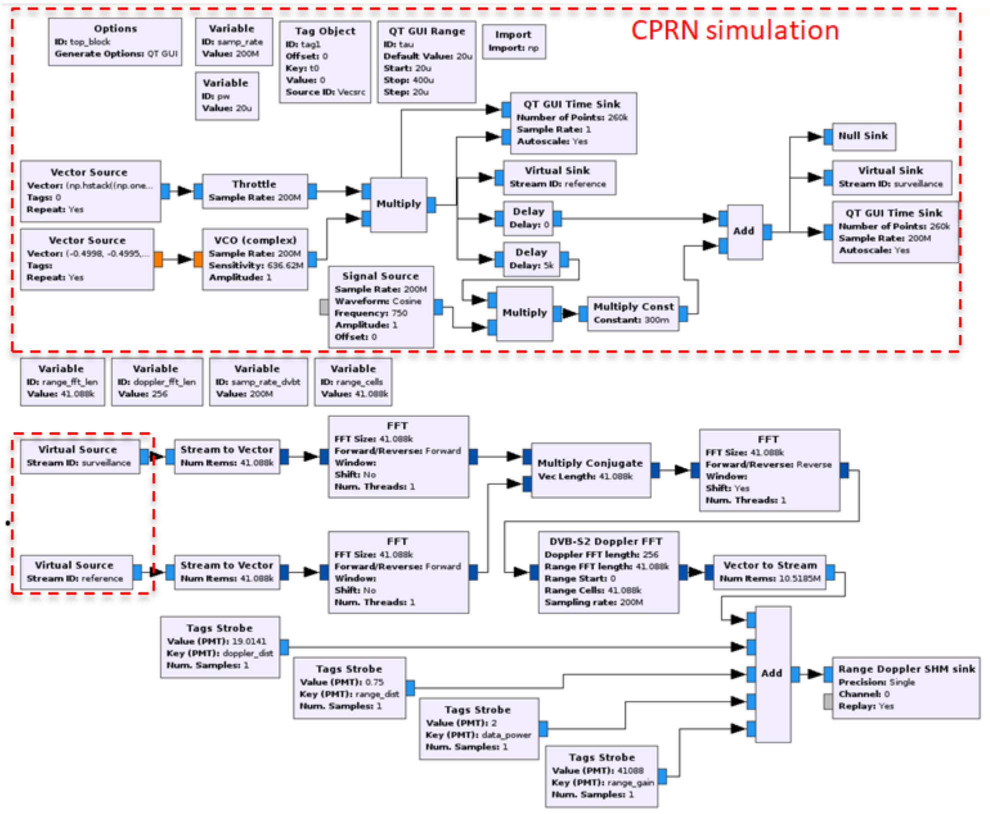

Figure 6 – Architecture to simulate the system combining CPRN and PR

By making se of this architecture, the initial simulations were carried out using ‘GNURadio’ in order to assess the first results of the combined system (CPRN+PR). These results included: (i) target range and velocity map; (ii) detection timestamps; and (iii) target and PR GPS coordinate locations. On top of this, a software tool was developed to display the obtained results from the performed simulation – as illustrated in Figure 7.

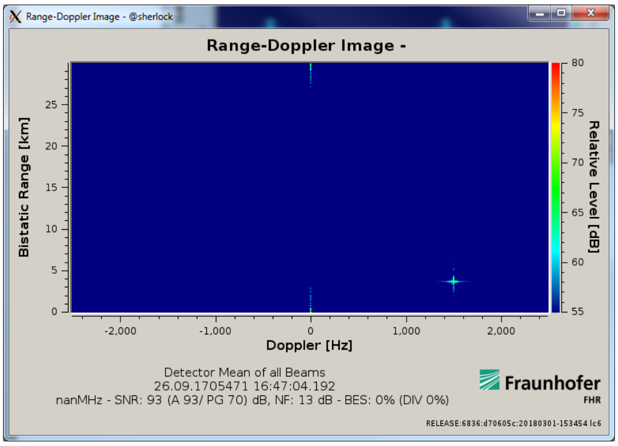

Figure 7 – Simulation results: range-doppler

Ultimately, it should be stated that the progress of the PR development met the timeline predicted for May 2018. However, no further progresses were made since then due to the FHR's suspension of works (due to the issue related with the distribution of the pre-financing).

T2.3: RF Signal sensor on board UxVs (M1-24), Lead: ELT

The main objective of T2.3, led by ELT, is the development and prototyping of a UAV-borne radio-frequency (RF) sensor that enables the interception and location of the origins of attacks against RF-links of the UAVs used in ROBORDER. In that sense, sources that imitate or intentionally disturb the RF-link among UAVs should be recognized and localized. The outcome of this task will be a prototype of this sensor based on the COTS SDR-platform provided by TEK, in which the software algorithms developed by ELT will be integrated. This task will be on-going until M24, but the so far achieved developments were reported in Section 3 of D2.2.

Phase 1: ELT Prototype & Software development

In the first phase, ELT GmbH developed its own prototype for test and validation. This prototype is composed by a ground-based sensor, which is also based on a SDR platform. The COTS-device used in this phase is the coherent multichannel receiver *USRP X310* equipped with the daughterboard *TwinRx.* Relevant specifications can be found in section 3.2.1 of D2.2. The following capabilities were enabled by the ELT Prototype: (i) RF detection, (ii) classification and (iii) direction finding.

To reach the 3D-direction finding capability, the front end of the system is equipped with a uniform circular array (UCA) that covers 360 ° in azimuth and 90° in elevation. Figure 8 shows one of the used antennas at ELT, which is composed of 5 bipolar antenna elements.

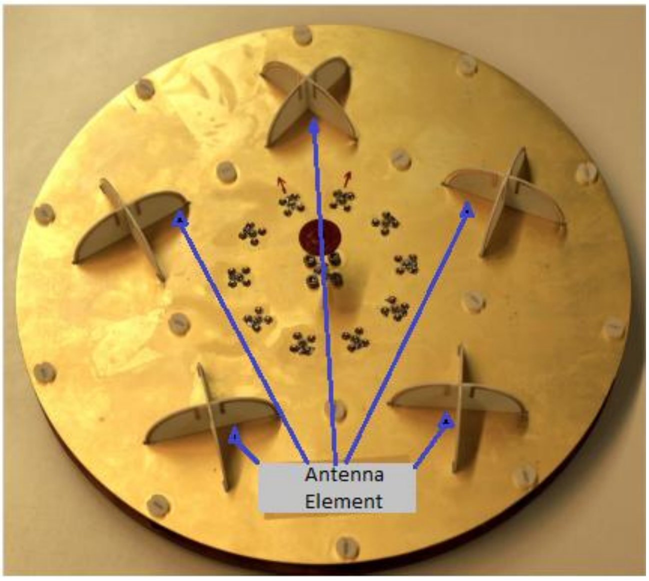

Figure 8 – Uniform Circular Array for 2,4GHz

Due to the antenna diversity (array) and the number of Rx inputs and their relatively low bandwidth of 80 MHz, ELT developed a switching strategy that allows the simultaneous exploitation usage of the different UCAs for different frequency bands. The details of this approach are shown in detail in section 3.2.1 of D2.2.

The first prototype has been installed on the roof of the MUROS-van for test & validation purposes. Figure 9 depicts the front end including the UCA and switching unit mounted on the van.

Figure 9 – First prototype: test under real conditions

From this test, it was concluded that: the direction finding was more robust for the azimuth estimation; and the elevation estimation is still not optimal. Further information can be found in section 3.2.1 of D2.2.

Phase 2 - Software integration in TEKEVER's SDR

The RF signal sensor under development in ROBORDER project will make use of TEKEVER's proprietary platform which is called 'GAMALINK': a communications and networking system that merges several innovative terrestrial technologies into a compact solution designed for small satellite market, but also compatible with any other platform. Its hardware is based on Software-Defined-Radio (SDR), an innovative concept that enables the development of various waveforms using a common hardware platform. The main characteristics of this platform can be found in section 3.2.2.1 of D2.2. The RF sensor setup was idealized as depicted in Figure 10.

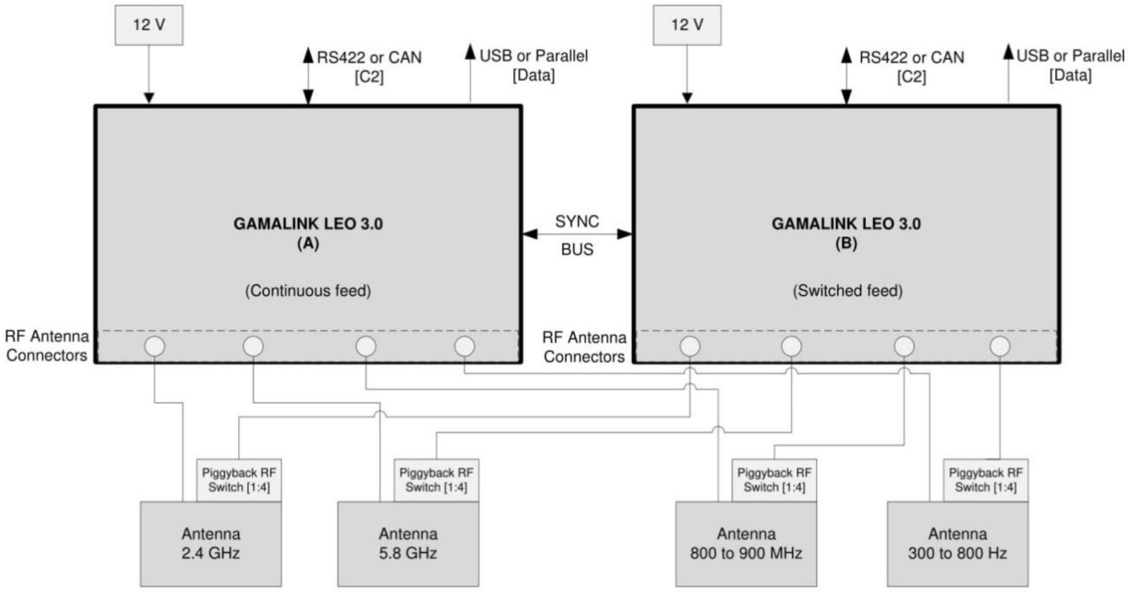

Figure 10 – RF Sensor Setup using GAMALINK platforms

As can be seen, the proposed setup will have two GAMALINK LEO 3.0 synced between themselves to guarantee the phase coherence between both receivers. One of these will be responsible for the acquisition of the continuous signal, while the other one will be in charge of acquiring the commuted signal between the multiple antennas.

For the proposed setup, four antennas are considered for four distinct bands, which are: 5.8 GHz, 2.4 GHz; 800 to 900 MHz; and 300 to 800 MHz (the most challenging to be achieved due to the low frequency and the necessary bandwidth). More details on the switching mechanism, as well as power and data interface specifications of the GAMALINK modules can be found in section 3.2.2.2 of D2.2. The processing performed in the modules is minimum, and it is only limited to filtering operations, re-sampling (if necessary), and conversion of data to deal with the digital interface requirements with the Payload server of the aircraft.The remaining signal processing algorithms (detection and classification) will be performed on the payload computer onboard the UAV platform. Two approaches on the processing approaches are currently being studied, near real-time and real-time processing. The details on these approaches can be found in section 3.2.2.3 of D2.2. As a final remark, the use of a high level language is not excluded from the real-time approach. However, it raises several concerns about the timings and performance of the algorithms. This will be further discussed between TEK and ELT before next steps in the sensor development take place.

T2.4: Sensors Adaptability (M1-24), Lead: ELT

Through the activities of task T2.4, the Consortium seeks, under the leadership of ELT, the design and development of a simulation environment tailored to the needs of the ROBORDER system. The related work departs from the project requirements previously defined in task T1.1 and is intended to cover all the use cases of relevance, identified beforehand in task T1.4. Complementing the implementation of the simulation framework, the main output of this task will also include a SIMROB library, in which every asset and associated models developed in the scope of WP2 are defined.

The existence of a reliable simulation engine is of the utmost importance in the development of the ROBORDER system, as the analysis of simulation results for the different use-cases may provide important insight and contribute towards the early identification of issues.

The development of SIMROB started out as an adaptation of a proprietary advanced simulation environment owned by ELT. The implementation of this framework includes several software applications and supports complex capabilities, such as System Analysis (SYA), Integrated Testing (ITG) and Training (TRA). The reader is referred to section 4 of deliverable document D2.2 for further information.

The virtualization of the physical world is implemented in SIMROB as a conceptual separation of a kinematic domain and an electromagnetic domain. Accordingly, two kinds of entities are considered – *Platform* and *Device*. The former includes all UxVs, manned aircraft, patrol cars, patrol vessels, ground sites and every moving and non-moving carrier of interest in the ROBORDER context. The latter consists of an abstraction to include different RF devices, such as sensors, radars and communication devices. The software provides all the necessary functionality to realistically simulate a scenario in which *Devices* are influenced by a dynamic electromagnetic spectrum, while being carried by a *Platform* (possibly moving) in a kinematic world.

The most relevant adaptations performed to the original system are the inclusion of models for all the different platforms used in ROBORDER (UAV, UGV, manned aircraft, MUROS-C van, suspicious person) and the RF sensor developed in Task 2.3, the implementation of the concept of clearance levels for filtered authorizations, the improvement of the graphical interface and the optimization of the run-time performance.

A test use-case is presented in deliverable D2.2, showcasing the working principles of SIMROB, how the setup of a simulation is intuitively performed and all the implemented functionalities. Figure 11 below provides a screenshot of a running simulation, in which is possible to observe that the different *platforms* and corresponding *devices* and any suspicious individuals can be tracked with the GIS map.

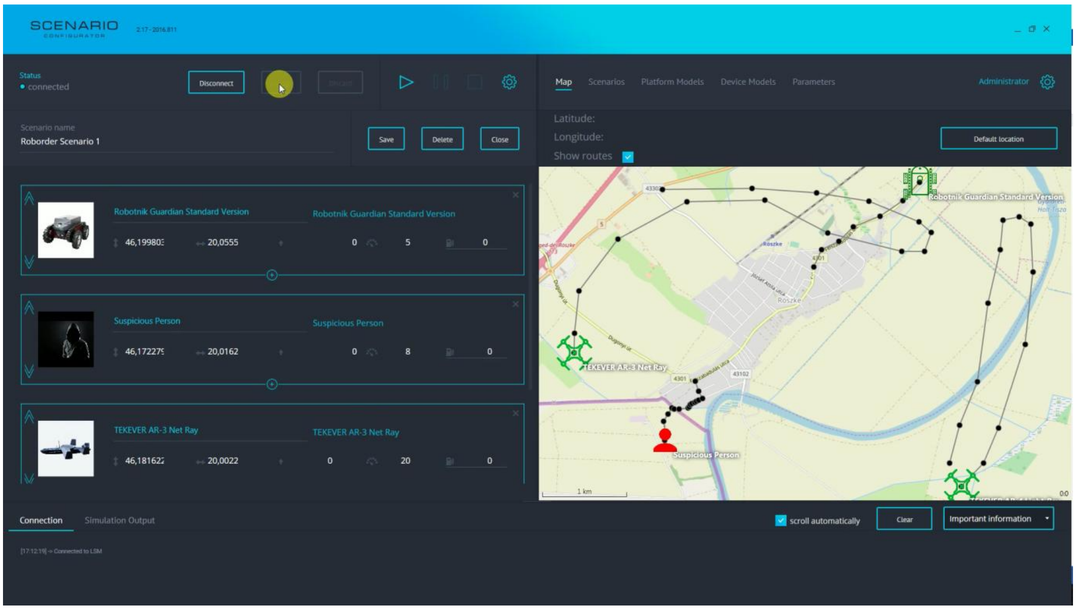

Figure 11 – SIMROB platforms in the GIS map

In that same test case, it was shown how enhancing the *platforms* with adaptive path optimization can contribute to increase the chances of success in detecting and tracking suspicious individuals. This is replicated in **Figure 12** – the top screenshot shows that using fixed paths might degrade the chances of success in detecting an individual crossing a border illegally because he/she may fall outside the regions of high probability of detection (PD) of the different *devices*, as shown on the left. Increasing the level of interaction between *platform* and *device* by adapting the trajectory of the former based on the estimate of the direction and angle of arrival might lead the sensor towards the suspicious person and bring him/her to the region of high probability of detection, thus increasing the chances of successfully detecting and tracking the trespasser.

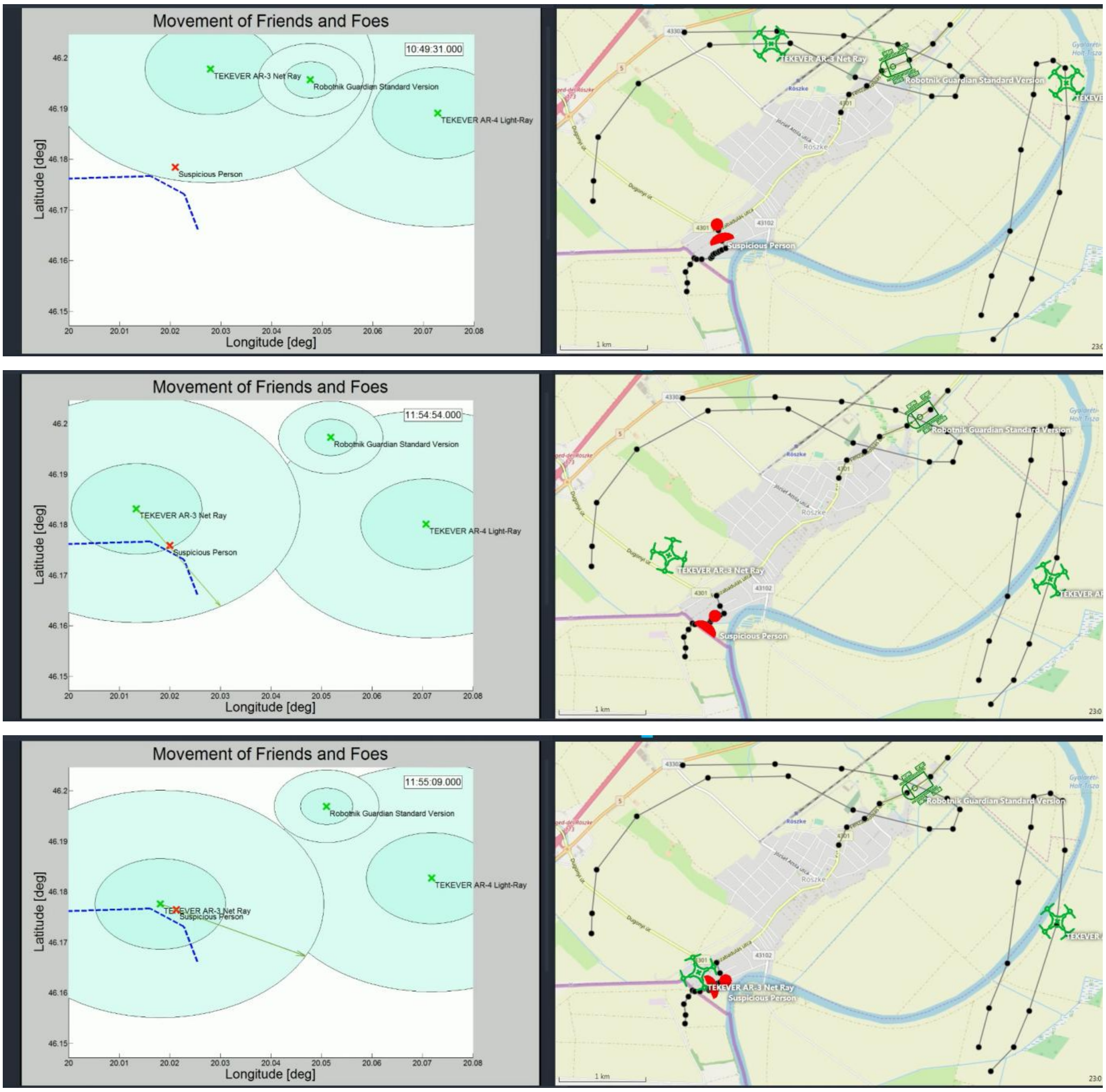

Figure 12 – SIMROB use-case with adaptive path optimization based on sensor PD. The border is represented by the purple line and the blue circles represent the high and low probability of detection regions for each device

T2.5: Re-configuration of agents and carrier solution (M1-24), Lead: ROB

The scope of this task is robotic platforms and sensors to be adapted for operation in adverse environmental conditions. A ruggedized solution for the UGV and the development of a UAV carrier solution are the main challenges of the task. In this sense, the understanding of the actual harsh environments where the system is going to operate was crucial.

Apart from the documentation of different use cases proposed by end-users in WP1, the feedback gained during physical meetings has been key to address specific issues like the terrain that UGV has to patrol and the specific sensor need and their positioning.
Hungarian border example led to realizing the need to move the UGV subsystem to a bigger platform.

Standing at the same TRL, ROBOTNIK's proposal switched from a track based rover (i.e. ROBOTNIK's GUARDIAN model) to an autonomous cart robot (based on Robotnik's RBCAR model) which will be able to patrol dirt roads even with mud, snow and unevenness of the soil.

Figure 13 – Soil Example in real Testbed

Standing at the same TRL, ROBOTNIK's proposal switched from a track based rover (i.e. ROBOTNIK's GUARDIAN model) to an autonomous cart robot (based on ROBOTNIK's RBCAR model) which will be able to patrol dirt roads even with mud, snow and unevenness of the soil.

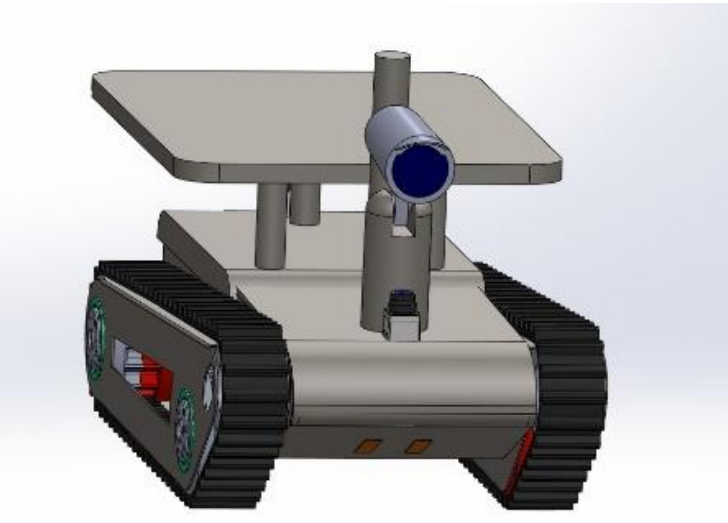

Figure 14 – Previous design concept

Figure 15 – Robotnik's RBCAR

In this case, the redesign is taking into account the following points:

- Automation of electric cart performed on a 4wd cart with higher clearance and suspension for harsh terrain.
- Possibility of keeping the manual drive, allowing the mapping operations and on-site mobile surveillance done by a border officer.
- Carrying capacity increased, including the installation of an elevation crane to position the sensor load up to 3m high.
- Allocation of separate batteries supporting longer sensor reading (thermal and regular camera stream).
- Robot electronics protected against bad weather conditions: IP65 electric cabinet with IP65 heat exchangers. Ruggedized connectors and battery holders.
- Weatherproof sensors: IP44 thermal camera, IP65 front LIDAR, IP65 RGBD camera.
- Bigger allocated space for drone landing platform. Tethered and untethered.

Figure 16 – RBCAR ROBORDER adaptation

For the last point on the carrier agent, an analysis has been made on the actual technologies available and the specification of the usable drones provided by COPTING.

Figure 17 – UAV for carrier solution by Copting

At this time, the ROBORDER RBCAR adaptation is being manufactured at Robotnik's premises, including in this process the integration of a 3m commercial crane and the customization of a commercially available 4wd UTV Polaris Ranger EV.

Ultimately, regarding the integration of the robot GCS with the ROBORDER system, the communication API has been tested with high level messages according to the results in D6.6.

T2.6: Photonics-based radars (M3-24), Lead: CNIT

The aim of T2.6, led by CNIT, is designing and developing a network of photonics-based radars, connected within each other through optical fibers. The radar network is intended to be deployed at the Port of Livorno, exploiting the available fiber infrastructure, and will implement innovative features (dual-band operation, coherent MIMO processing) that will improve the performance of the radar detection and tracking, in particular achieving a very high cross-range resolution. The radar network will control the access to the Port of Livorno, aiming in particular to detect small boats (e.g., rigid inflatable boats) that could represent a threat (see PUC 1.6).

The radar network is based on the coherent multi-static approach, leveraging on the intrinsic high coherence and low transmission loss of photonics.
The design of the whole radar network and of its subsystems has been finalised, starting from the definition of the main radar parameters and considering the targeted performance in a maritime scenario. The constellation of the radar networks will make use of three radar peripherals, working simultaneously on two frequency bands (namely, in the S and X bands). The master laser that synchronizes the entire radar system is going to be realized by CSEM, following the specifications provided by CNIT.

The possible geometries for the deployment of the radar peripherals at the Port of Livorno have already been considered. This is important due to the influence of sensors distribution geometry on some design parameters, such as the radar maximum range, the covered area, the signal distribution, the peripherals control and so on. These parameters, on their turn, affect the antennas orientation and radiation patterns, the maximum transmitted power, the cross-talk level, the pulse repetition frequency.

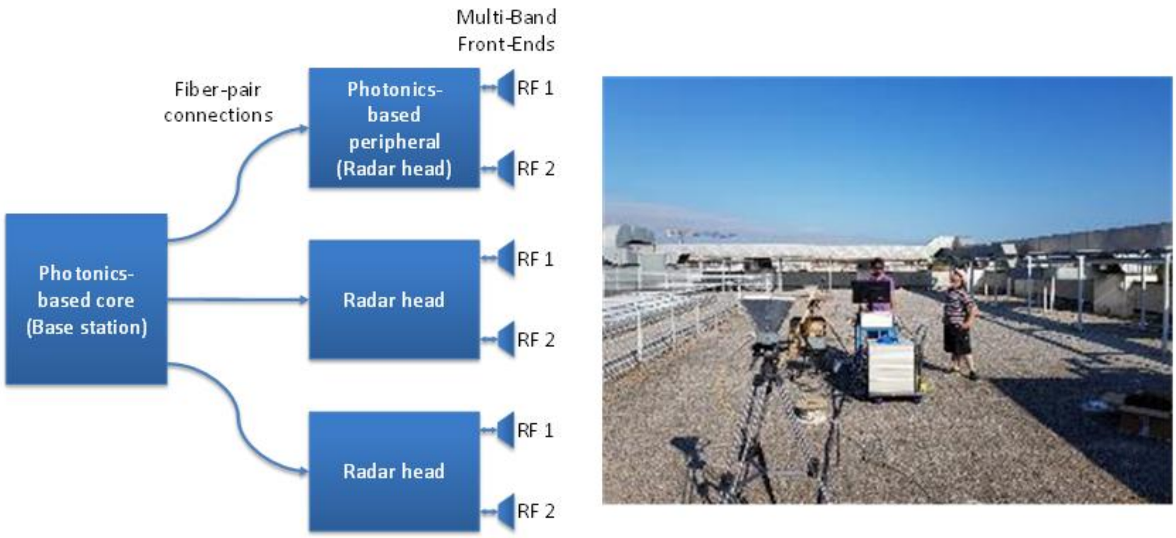

Figure 18 – Functional scheme of the photonics-based multi-band coherent radar network, and a picture from the preliminary simplified field experiment

As the design of the full radar network is largely finalised, the implementation of the demonstrator is moving forward very quickly. Meantime, preliminary experiments with a simplified photonics-based radar network have already been run (aiming at a UAV from the roof of the CNIT lab), to test on the field the main performance of the hardware and software sub-systems (see T3.2).

The development of the optical clock (or master laser) by CSEM has followed two parallel activities before merging the results in the 600-MHz packaged laser that will finally be delivered to CNIT for integration in the final radar network.

The first aspect is related to packaging for realizing a robust and reliable laser. The packaging technology was developed with a similar 400 MHz oscillator. Several aspects with this technology were not fully mastered. Indeed, the fixing of the cavity elements was not efficient. In particular, misalignment happened while fixing them. Now, solutions have been found and implemented. The 400-MHz oscillator has been reassembled several times successfully. As a conclusion, the packaging technology is validated and will be implemented for the 600-MHz master laser.

The second aspect was to identify a working cavity design for the 600-MHz oscillator. A laboratory prototype has been built (see picture below) and optimization of the laser parameters (pulse spectral bandwidth, output power and mode-locking threshold) served as criteria.

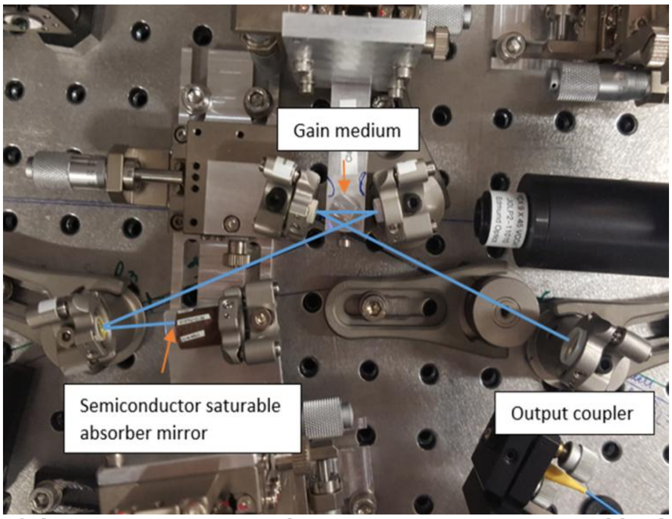

Figure 19 – **Picture of the 600-MHz laser laboratory-style prototype (the blue lines are for the intracavity beam)**

A suitable cavity is now available and based on that a packaged laser has been designed. This design was complemented with finite-element modelling (FEM) simulations to optimize structural and thermal properties. In particular, the deformation of the plate with respect to temperature gradient was investigated. In addition, the eigenmodes of the structure have been simulated. With a first eigenmode at a frequency of 452 Hz, the structure is considered very stable and robust. Special emphasis has been made in designing a compact laser head. Optics with diameter of 8 mm allows reducing the overall height of the laser head to 40 mm for a footprint of 270x150 mm^2.

At the current status, the 600-MHz master laser has been fully designed and its design has been thoroughly analyzed in terms of laser performance as well as mechanical and thermal properties. The detailed design is finished and the parts have been ordered. Once the parts are received, the next steps towards the full laser will be:

1. Assemble the prototype;
2. Test and optimize it with laboratory electronics;
3. Develop and implement product-like electronics; and
4. Characterize the full optical clock.

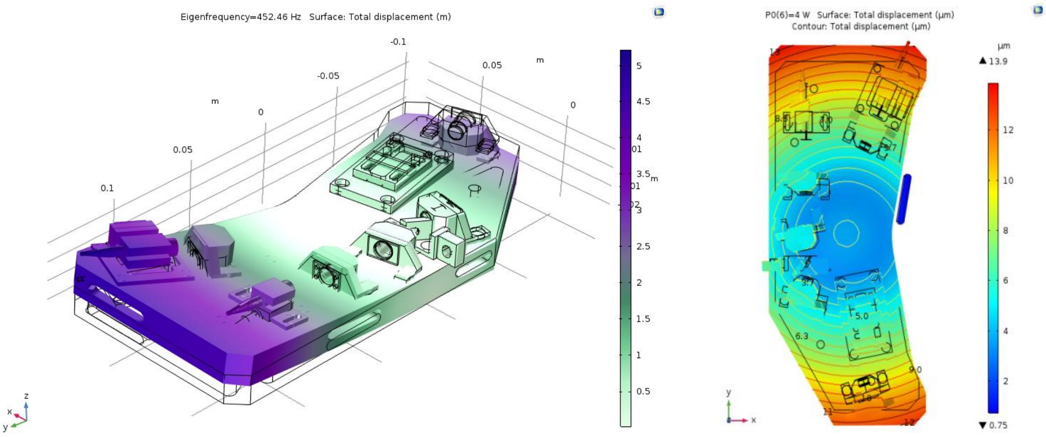

Figure 20 – **Left: FEM structural simulation with first eigenmode at 452 Hz; Right: Displacement due to temperature gradient in the base plate with 4 W total heating power**

1.3.2.1 WP2 Risks

This section presents the current WP2 risks.

Work Package 2 Risks	
Risk 1	The issues related with the distribution of the pre-financing affected the envisioned developments for some of the WP2 tasks, namely T2.2, T2.3 and T2.4.
Risk 2	Error in packaged master laser design. The design is based on the lab-style laser, and on the packaging technology developed for the 400 MHz oscillator. A design review meeting involving three persons happened before ordering the parts to minimize the risk of errors.

Table 6 – Work Package 2 Risks

1.3.3 Work Package 3

Work package number	WP3	Start month	1	End month	24
Work package title	Detection and identification of border-related threats				
Lead partner	CNIT				
Contributing partners	TEK-AS, CERTH, FHR, EASS, PSNI, GNR, ORFK, ROB, SPP, ELTM, HMOD, CENTRIC, APL, OMST, BDI, UoA, MJ, CPT, RBP				

The objective Work Package 3 is to perform detection techniques for pollution incidents, identification and tracking of illegal activities, detection of radio-frequency communications signals, as well as detection of communication-based cyber-attacks to the operation of ROBORDER's autonomous systems. It is also expected to deploy low-level fusion techniques from heterogeneous sensing platforms in order to enhance the recognition capabilities.

The following section includes the advancements that have been performed for the corresponding WP3 tasks, as well as the current status of their implementation. The analysis is provided per task.

T3.1: Detection of pollution incidents (M1-24), Lead: CNIT

A framework has been deployed by CERTH for oil spill detection in images acquired from a SAR sensor and relies on the "DeepLab"[5] model, which is considered as one of the state-of-the-art model in semantic segmentation. The model can semantically segment oil spills and other regions of interest over an input SAR image. Currently, the deployed model is capable to detect five classes including oil spills, look-alikes, sea surface, land and ships.

The advantage of this approach towards other image classification models includes the annotation of every image pixel instead of labelling the entire and/or a portion of the image. Thus, images containing multiple instances of each class, a common scenario in observation tasks, can be properly handled by the current framework. In comparison with the regular object detection models, the deployed segmentation approach can identify an object and approximate the corresponding shape instead of assigning a bounding box. Oil spills present high variability in shape and size, thus acquiring information about those features is crucial in that case. In order to train and evaluate the deployed model, a dataset was created by collecting SAR images from an open access framework of the European Space Agency

[5] Chen, Liang-Chieh, et al. "Deeplab: Semantic image segmentation with deep convolutional nets, atrous convolution, and fully connected crfs." *IEEE transactions on pattern analysis and machine intelligence* 40.4 (2018): 834-848.

(ESA), the Copernicus Open Access Hub. Information about confirmed oil spill events was provided from European Maritime Safety Agency (EMSA) through the CleanSeaNet service.

For every SAR image, a ground truth mask was created where instances of each class were colourized with a distinct colour. The developed dataset consists of 1000 images for training and 110 images for the evaluation process. For every input that was semantically annotated by the model, the number of detected oil spills is calculated. In addition, targeting an increased situational awareness, the size of the largest oil spill and the minimum Euclidean distance from a coastal region (if detected) can be estimated. Currently, these values are pixel-counted. However, if the SAR sensor resolution is defined, the extracted measurements could be converted into real world units (meters, square meters). This information is stored in a JSON file while it is forwarded to T4.4 for extracting further information.

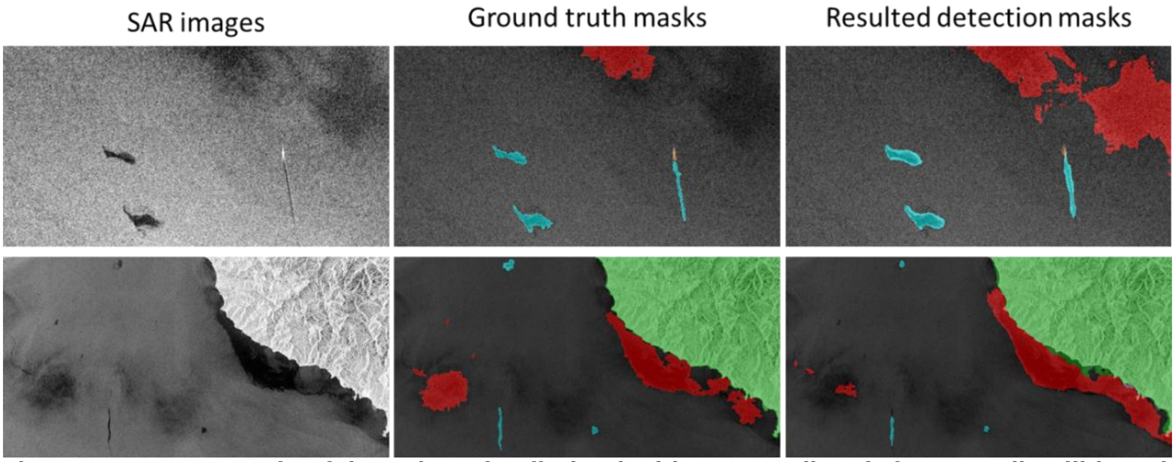

Figure 21 – An example of detection of pollution incidents; Predicted classes: *oil spill* (cyan), *look-alike* (red), *ship* (brown), *land* (green)

The corresponding research for semantically segment SAR representations resulted into two publications[6,7]. The initial work deployed a deep convolutional neural network (CNN) model to identify only oil spills and look-alikes. An extended version of the proposed deep CNN model combined with a multi-scale analysis focused the extreme variability that oil spills display in size and shape. The second model is capable to annotate instances of the 5 classes.

T3.2: Identification and tracking of illegal activities (M1-24), Lead: CNIT

For identifying instances in the visual field of each UxV, CERTH has developed a framework for parsing video sequences or static images and perform object detection and tracking. The detection model relies on a deep learning architecture, the Faster R-CNN[8], which is considered as one of the state-of-the-art in object detection. On the other hand, the tracker is based on Kernelized Correlation Filters (KCF)[9], which is also considered as one of the best available options. Detection and tracking are applied interchangeably: a detection is applied on frames, and tracker is applied on a sequence of frames. The main advantage of this approach is the faster video parsing in comparison with the simple object detection

6 Orfanidis, Georgios, et al. "A Deep Neural Network for Oil Spill Semantic Segmentation in Sar Images." *2018 25th IEEE International Conference on Image Processing (ICIP)*. IEEE, 2018.

7 M.Krestenitis, G.Orfanidis, K.Ioannidis, K.Avgerinakis, S.Vrochidis, I.Kompatsiaris, “Early Identification of Oil Spills in Satellite Images Using Deep CNNs”, International Conference on MultiMedia Modeling, January 2019, Thessaloniki, Greece (accepted for publication)

8 Ren, S., He, K., Girshick, R., & Sun, J. (2015). Faster r-cnn: Towards real-time object detection with region proposal networks. In *Advances in neural information processing systems* (pp. 91-99).

9 Henriques, J. F., Caseiro, R., Martins, P., & Batista, J. (2015). High-speed tracking with kernelized correlation filters. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *37*(3), 583-596.

application. The number of classes that our framework is trained to identify is currently eleven instances and involves among other humans, weapons, cars, trucks, buses, boats, helicopters etc. The model is trained upon a collection of publicly distributed datasets as well as some restricted images (especially for weapon objects). The total number of samples is 10243 images of which around 830 are related to weapons. The outcome of this module is propagated to T4.4 and also to the activity identification module of the same task. Finally, the framework is also capable of producing object-annotated videos if this is required.

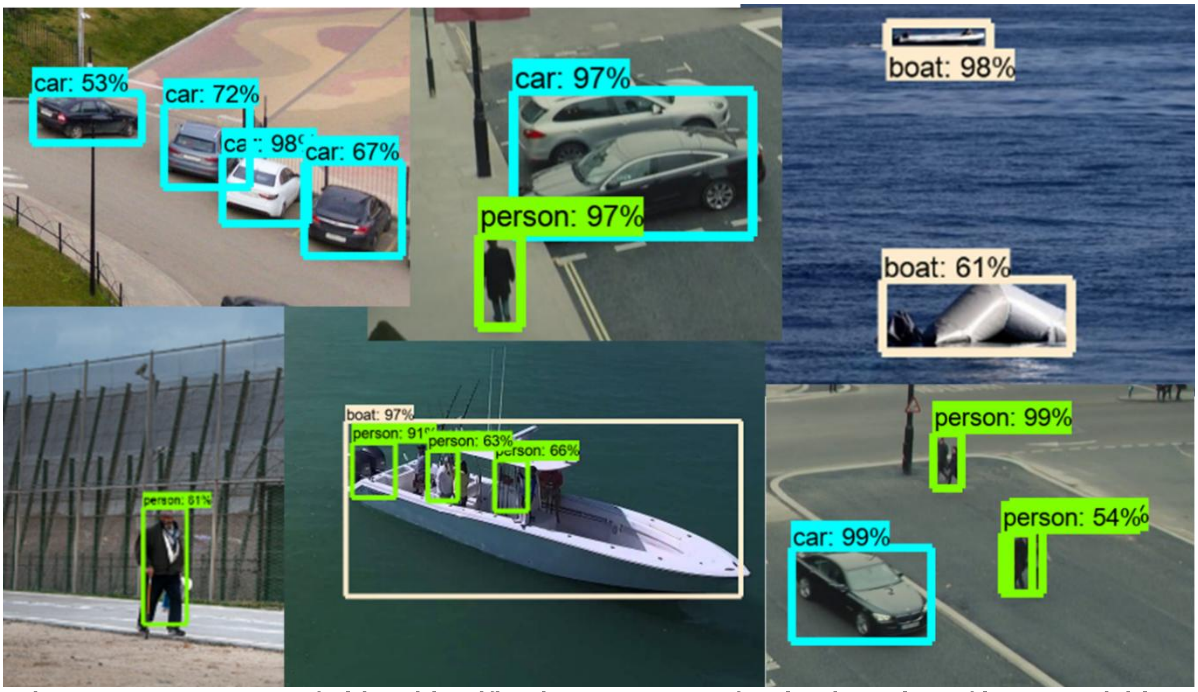

Figure 22 – Examples of object identification, necessary for the detection of illegal activities

HOG-HOF features (Histograms of Oriented Gradients - Histogram of Optical Flow), i.e., spatiotemporal features, are extracted from detected objects in order to identify simple activities involving humans and vehicles. The objects that can be detected and tracked are denoted with a unique object id and some coordinates.

The output of the detected objects will then be used by CENTRIC to categorise the illegal activity that can be seen in the video or image. Currently, the tracking of objects across frames is implemented with associated overlays showing the direction and the object label. The tracking of objects is also robust against image distortion such as a camera shaking. To identify illegal activities through the tracking of objects between frames features, such as object size, direction, speed, and the types of interaction between the objects in question to identify the ontological concepts as indicators of illegal activity that is being seen at that moment in time. For example, a sudden burst of speed across a border is a potential indicator of an illegal activity, as could be changes in position, or objects moving in directions opposite to the majority of the other objects.

The identification and tracking of illegal activity module developed by CENTRIC will also feed into the visualisation module (T4.4) to provide clear visualisations that allow an operator of the ROBORDER system to track the situation as it develops. What may be a low risk of a single person may suddenly escalate when suddenly a large number of people are detected within the area.

Figure 23 – An example of the objects identified and given a current speed value and a direction arrow

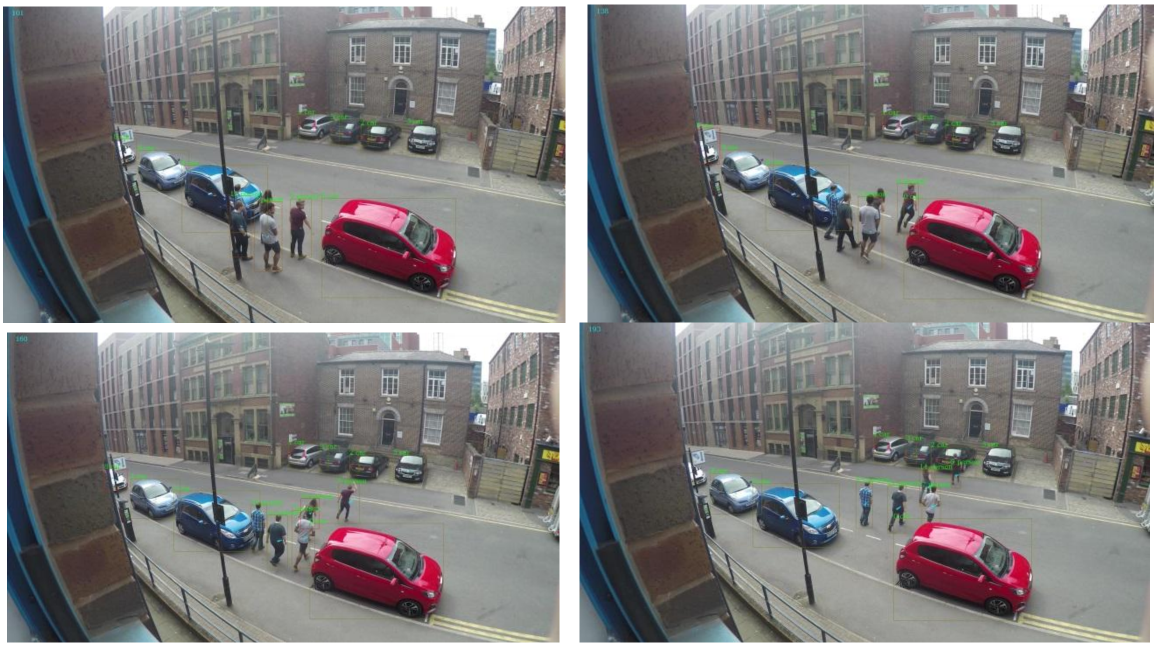

Figure 24 – Examples of tracking of people objects

Figure 25 – Examples of tracking vehicles across frames

The identification and tracking of illegal activities can also take advantage of the detection from radars. Within ROBORDER, CNIT is designing and developing a network of photonics-based radars, connected within each other through optical fibers (see description of T2.6), which will implement innovative features as dual-band operation and coherent MIMO processing that will improve the performance of the radar detection and tracking.

The radar network will be installed at the Port of Livorno (in collaboration with APL), and the processed radar data will be made available to the MONonitoring and Control Application (MONiCA) that manages the data collected in the Port by other platforms (AIS data, visible and IR cameras, etc.). Then, the data platform of the Port will make all the data (from the radar network as well as from other sources) available to ROBORDER.

In T3.2, CNIT is developing the processing tools for extracting the high-resolution detection and tracking from the raw data of the radar observations. The processing tool under development considers the geometry of the antennas in the radar network, and returns a range/cross-range map. The operation first considers a low-resolution analysis, with the aim of identify possible targets in the observed scene. Then, exploiting the coherence of the data acquired by the network of radars, a MIMO processing is used to implement a high-resolution analysis in the areas where possible targets have been spotted. This analysis can reach a resolution far better than the one guaranteed by a single radar (i.e., not organized in a coherent radar network) with the same features.

Recently, a preliminary field experiment has been run with a simplified radar network, allowing to successfully testing the developed processing tools.

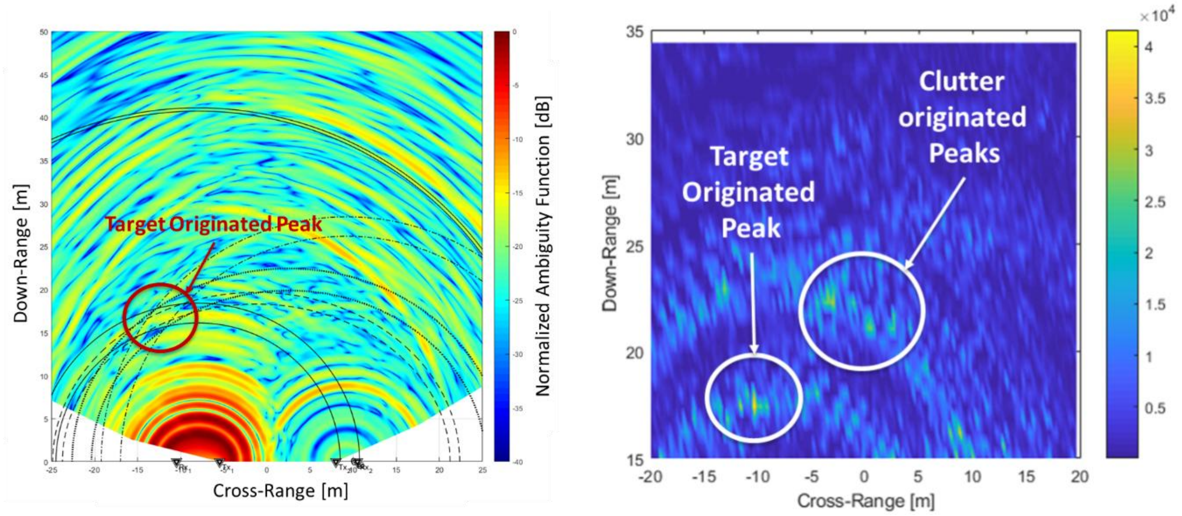

Figure 26 – Detection results from a field experiment. Left: low-resolution (non-coherent) detection; Right: high-resolution detection from coherent MIMO processing

Currently, the processing is being improved to suppress the peaks originated by the clutter. Moreover, the communication between the radar network and the Port data platform is going to be simulated, in order to advance on the interfacing between radar network, Port platform, and ROBORDER platform.

T3.3: Low level fusion of sensor data (M1-24), Lead: CERTH

In the context of this task, CERTH has deployed a framework capable to fuse data from visual cameras and IR/thermal sensors. In fact, depending on the environmental conditions and the operational time, some objects could not be detectable in the visual spectrum, so relevant infrared sensors could overcome such limitations improving the detection capabilities.

The fusion scheme relies on maximizing the inclusion of information from the acquired data and consists of two processing phases. Initially, representations acquired from visual and IR/thermal sensors are decomposed in a predefined number of components with the application of the Fast and Adaptive Bidimensional Empirical Mode Decomposition (FABEMD) algorithm[10]**.** Current approach is superior to the basic Bidimensional Empirical Mode Decomposition (BEMD) approach due to its increased processing speed and its adaptiveness. The second phase of the method applies a fusion scheme at component level of the data, in order to produce the final fused signal. Thus, an amount of the exploited information from each component of the decomposed input signals has to be defined, while optimal fusion is achieved by optimizing information metrics such as entropy, negentropy, etc. Towards this direction, Particle Swarm Optimization (PSO) method is deployed to fuse multi-modal data in a fast way, while the contained information into the fused "image" is maximized. Fused data is considered as an output image of this framework and is forwarded to T3.2 for optimal identification.

[10] Bhuiyan, S. M., Adhami, R. R., & Khan, J. F. (2008). Fast and adaptive bidimensional empirical mode decomposition using order-statistics filter based envelope estimation. *EURASIP Journal on Advances in Signal Processing*, *2008*(1), 728356.

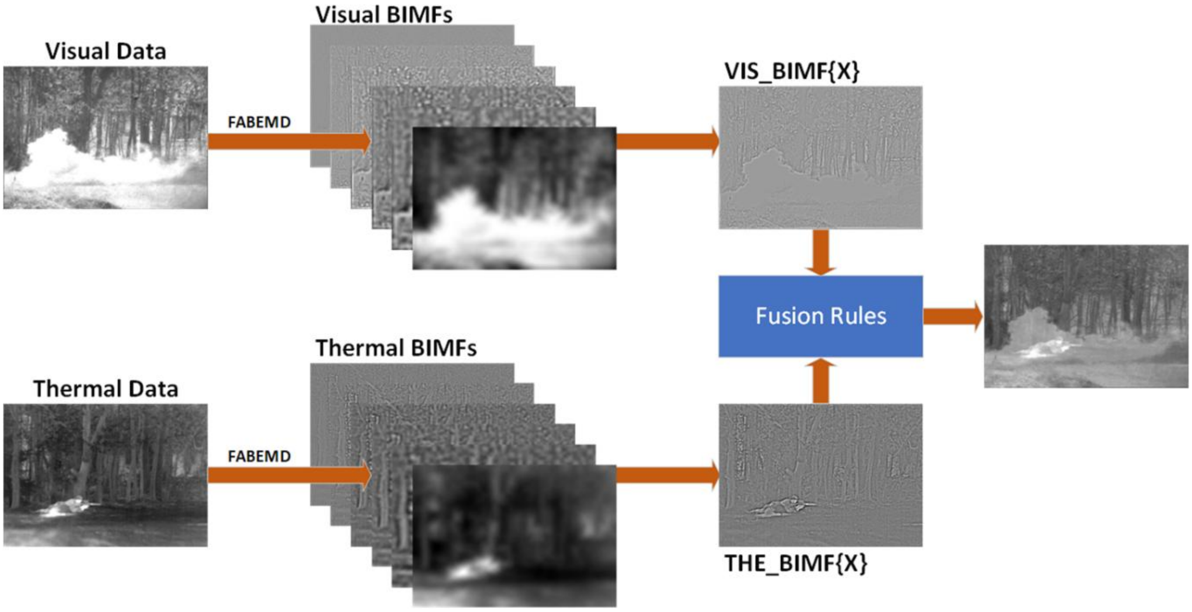

Figure 27 – Example of a low-level data fusion between visible and thermal infrared images

Currently, the algorithm is already working. Few modifications are under implementation to reduce the processing time. Moreover, additional datasets of simultaneous visible and thermal images are being sought to better test the algorithm. These datasets are likely going to be provided by project partners producing UAVs with on-board cameras.

T3.4: Detection and classification of cyber and cyber-physical attacks (M1-24), Lead: CPT

In the context of Task 3.4, the Intrusion Detection and Classification Module (IDCM), which is under development by CPT, is responsible to detect and classify both cyber and cyber-physical attacks against the ROBORDER system.

The IDCM module uses statistical-based reasoning and deep learning-based reasoning techniques. It needs to go through (i) a learning phase to learn the environment, (ii) a testing phase to tune the parameters, and (iii) an evaluation phase. It is developed in C language to avoid system specific dependencies, and uses Valgrind memory debugger to identify memory leaks and optimize the memory usage. The IDCM module has been developed with multiple interfaces for being able to access the ROBORDER system's data (i.e., CAN bus and CSV files format), and has a Multi-Threaded Support for network functionality. Other networking capabilities of the module include TCP/UDP protocol stack support and cloud service support.

From an integration point of view and to demonstrate the system's operability with the ROBORDER system, during the integration week, an instance of the IDCM module has been running in TEKEVER's cloud environment and has been collaborating with the ROBORDER system. The IDCM module showed that it is capable to successfully authenticate with the system, query the system for available assets and request data from specific assets (from a simulated UAV in particular, which was connected to the system at the time).
During the reporting period, various experimentations were conducted using data from two project partners, namely Copting and OceanScan. The overall average classification accuracy of normal behaviour for the given data across all data sources are as follows: COPTING – 96.1%, OceanScan – 91.6%. The average time for processing a single data source was: Learning Phase 0.61 ms, Testing Phase 0.54 ms, and Evaluation Phase 0.52 ms.

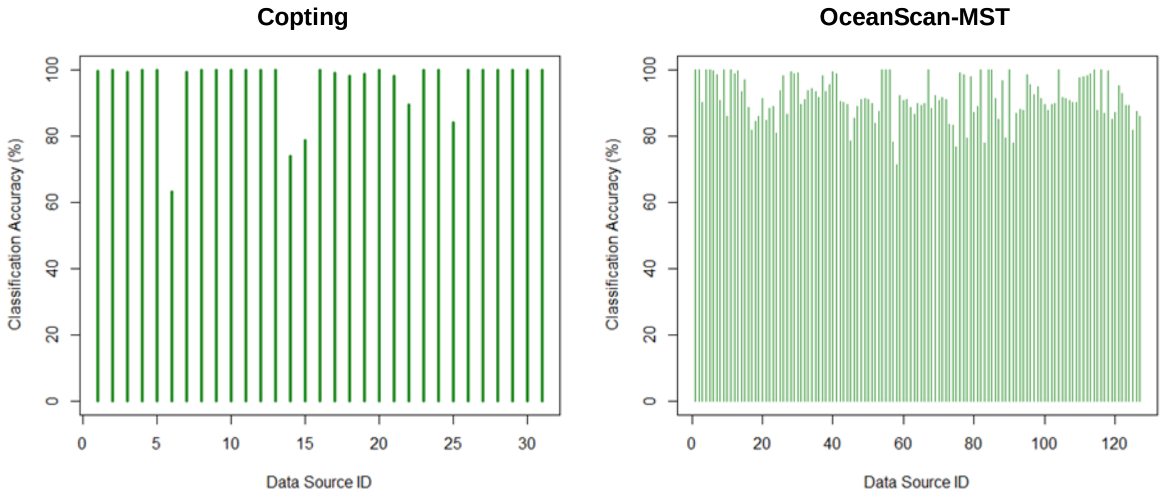

Figure 28 – Results of the experiment running the IDCM on real communication data

The planned activities for the next reporting period would be to further test the IDCM module and check its behaviour in more complex scenarios (i.e., in presence of parasitic data sources). This would require IDCM to have access to real robotic data, i.e., data from robotic vehicles connected to the ROBORDER system including internal robotic vehicle data as well as data from the communication of the robotic vehicles with the ground station. This data would allow the IDCM module to create accurate cyber-physical behaviour signatures prior to the vehicle's connection to the ROBORDER system. For testing purposes, synthetic data could also be used. However, synthetic data may not necessarily represent the real-world environment, and this may have an undesired impact on the detection accuracy on the IDCM module.

T3.5: Identification of unauthorized communications using RF sensors (M3-24), Lead: TEK-AS

Task 3.5 comprises the development of the detection and identification algorithms to be integrated within the RF signal sensor. These algorithms are in development by ELT, while the integration will be made closely with TEK-AS.

Under the scope of T2.3, which consists in the development of the RF signal sensor, the initial testing of the detection and identification algorithms has been performed – as reported in this document in Section 1.3.2. These tests were performed in both laboratory and real operational conditions, and intended to assess the initial performance of these algorithms before its integration in the RF sensor in development for ROBORDER project.

Since the sensor is still under development, it is expected that the integration of the algorithms will be performed during the 2nd cycle of developments envisioned for the project, thus no more advancements on T3.5 are to be reported so far.

1.3.3.1 WP3 Risks

This section presents the current WP3 risks.

Work Package 3 Risks	
Risk 1	Poor datasets for training the detection algorithms (SAR images for T3.1, fused visible/thermal images and videos for T3.2). The algorithms are already working;

	this risk could only affect the initial performance of the algorithms.
Risk 2	Poor dataset of visible+thermal images or videos to test the low-level data fusion (T3.3). The fusion algorithm is already working; this risk could only affects its initial performance.
Risk 3	Poor dataset of real communication data from UAVs (T3.4). This risk could significantly limit the effectiveness of the IDCM in real conditions. Mitigation is sought by collecting real data from the project partners developing UAVs.
Risk 4	Low input regarding the real data that are required to evaluate the current versions of the services. Those data should be acquired from real missions using the existing assets.

Table 7 – Work Package 3 Risks

1.3.4 Work Package 4

Work package number	WP4	**Start month**	3	**End month**	24
Work package title	Command and control unit functionalities				
Lead partner	CERTH				
Contributing partners	TEK-AS, EASS, VTT, PSNI, GNR, CMRE, ORFK, ROB, SPP, HMOD, CENTRIC, APL, OMST, BDI, Copting, UoA, RBP				

The following section includes the advancements that have been performed for the corresponding WP4 tasks as well as the current status of their implementation/integration. The analysis is provided per task.

T4.1: Advanced human-robot interface (M3-24), Lead: VTT

The first version - Proof of concept: In Figure 29 can be shown main concept of using Microsoft Hololens mixed reality solution and virtual control table to use in UxV swarms mission control in border inspection. User can plan and control UxV swarms inspections areas on 3D virtual map and 'jump-in' to 3D map to see environment in real space. Also, user is able to see various sensor data from UxVs in augmented reality mode, which supports decision making of border control. The first proof-of-concept has been developed to collect feedback from various user groups, which supports to define the Concept of Operation of novel system.

Figure 29 – Proof of concept: Microsoft Hololens based UxV mission control

The second version - Functional prototype: The second version of the system already reached the functional prototype phase. User is able to monitor and/or control real UxV via VR and/or AR user interface. User is able to see UxV in 3D online 3D map and can monitor sensors values and choose camera streaming (see Figure 30).

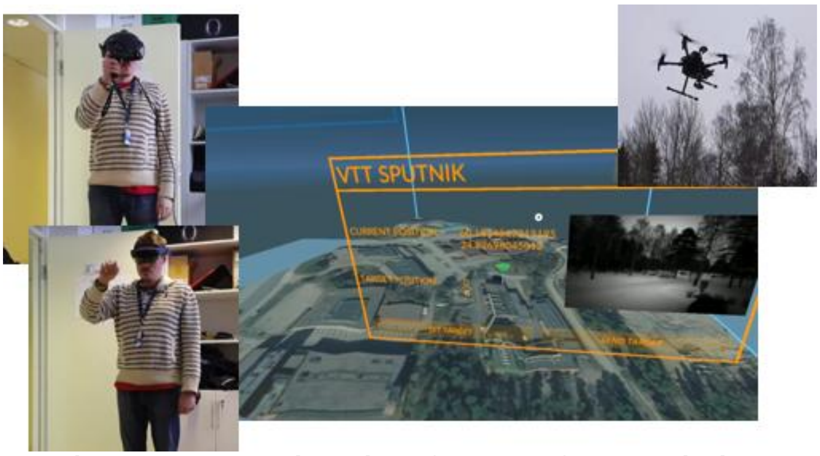

Figure 30 – Second version of Novel UI for UxV Mission

The mission planning and execution are supported e.g. defining end-point for UxV. System has been built in modular architecture, which allows to make application to AR or VR mode to various devices which are supported Microsoft Mixed Reality Toolkit (see Figure 31).

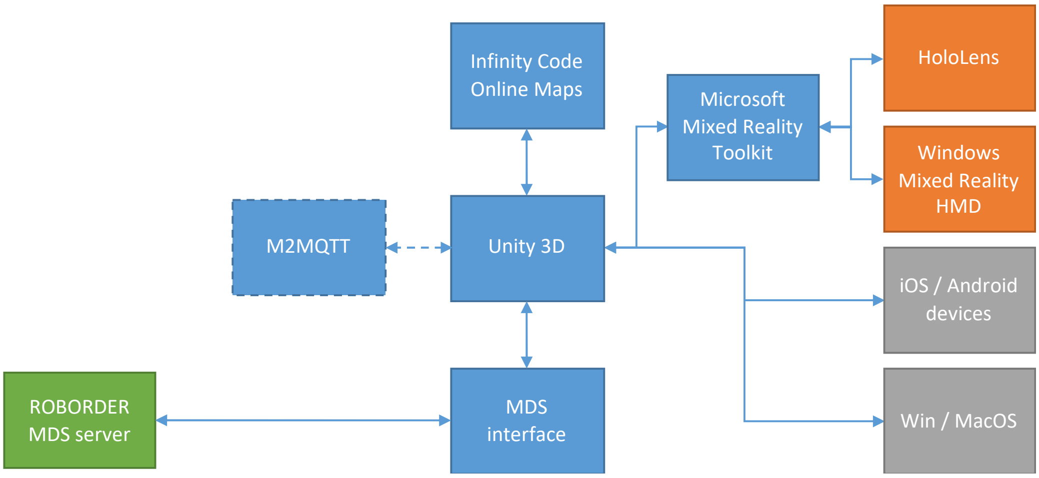

Figure 31 – The second version of the system architecture based on Unity3D and Microsoft Mixed Reality Toolkit

Also, the first version desktop and mobile devices are supported with limited features. User can follow UxV location in 2D/3D map and select the sensor data view of UxV e.g. Camera streaming. Example of the mobile UI can be seen in Figure 32.

Figure 32 – Mobile and/or desktop version of the Advanced Human-Robot Interface

T4.2: DSL-based mission specification (M3-24), Lead: UoA

This task refers to the development of the tools required in order to support the ROBORDER users in the definition of robotic missions for UxVs. These tools are using a web-based GUI to allow the users determine the behaviour and interact with the robotic assets. During the first half of the project, a mission planner has been built on top of a Mission Description Language (MDL). The ROBORDER MDL constitutes a domain specific language for the mission specification of the robotic devices. The MDL terminology has been defined to cover all the aspects of a mission, i.e., metadata, operation commands, event oriented commands and post-operation commands. Also, the syntax and the grammar of the language has been set. The MDL features not only spatial characteristics but also temporal management (attain waypoint x at time y – switch sensors at time z). Along with the specification of the MDL comes the design and implementation of the MDL-compatible development tools (DT) which increase mission productivity. The DTs come in the form of a textual and (fully equivalent) visual editor that are synchronised. A draft version of the two editors has been developed in the first half of the project; a) the textual editor allows the user to define the robotic mission by using the MDL syntax, and b) the visual editor offers to the user the capability to define a mission in more intuitive means (i.e., map-based visualisation of the mission and the resources, visualisation of waypoints, drag-and-drop functionality). In addition, a series of proofing and validation tools has been developed to support the editing phase. In particular, a generator has been implemented to inject and deliver the edited mission to the system. Also, a real-time validator that checks the DSL syntax and provides the user with errors and inconsistencies that have been detected at each step is offered. Finally, a set of assistive functionalities including auto completion and hovering functionality has been developed. During the integration phase, the mission planner has been integrated with the ROBORDER Dashboard under the same application. In this context, several types of messages have been exchanged between the mission planner and the rest of the ROBORDER modules to ensure that the planner may properly consume and communicate all the potential types of information (e.g., designed missions, involved UxVs, types of used resources). As a next step, we plan to enhance the expressiveness of the language according to the user needs and connect the mission planner module with real resources (e.g., sensors) and UxV assets.

T4.3: Autonomous resource task coordination (M6-24), Lead: CERTH

The progress in T4.3 “Autonomous resource task coordination” can be summarized in the following points. A new distributed algorithm has been developed and tested in simulation. This algorithm is specifically designed to coordinate multi-robot teams where the user-defined objectives of the mission can be casted as a general optimization problem without explicit guidelines of the sub-tasks per different robot. Instead of explicitly solving a particular problem, which requires prior knowledge of the system dynamics, the developed algorithm learns – from the real-time measurements – exactly the features of the system, which affect the user-defined objectives. The overall, low-complexity algorithm, can straightforwardly incorporate any kind of operational constraint, is fault tolerant and can appropriately tackle time-varying cost functions. Moreover, the following multi-robot scenario was developed. Assuming that a swarm of autonomous flying vehicles is available, the objective was to monitor the borders of a geographical area. In other words, the flying vehicles should be deployed in the operation area in such a way that the combined view of their sensors (cameras) acquires the maximum amount of information regarding the borderline. The developed algorithm was able to find the appropriate configuration for the swarm after some timestamps due to the time that is needed for the learning phase. It should be highlighted that the algorithm is able to handle situations where one or more robots leave or enter the swarm by adjusting the decision variables of the other robots without the need to stop and re-start the mission. The algorithm is at a pre-final stage, with still some pending refinements mainly due to the communication with the main ROBORDER messaging system.

T4.4: CISE-compliant common representation model and semantic reasoning (M3-24), Lead: CERTH

In the context of T4.4 (M3-M24), CERTH has developed a common representation framework based on EUCISE2020[11] for semantically modelling and integrating information from the various multi-modal sensors and other external resources (data fusion, risk analysis, face and object recognition). This framework is formalized as an OWL[12] ontology, which can be highly extensible in order to be used in a variety of scenarios. Such an extension is the ROBORDER ontology for semantically representing the project's PUCs, which is at a pre-final stage, with still some pending refinements due to the ongoing demonstrations. We deployed a Docker image with a GraphDB[13] triplestore (i.e. a DBMS for ontologies) for hosting the ontologies.

A tightly related thread within T4.4 has to do with semantic reasoning, which we implemented as rule-based reasoning (based on SPARQL[14] rules). The set of rules depends on the PUC and is still a subject of discussion with the use case partners – refinements are expected during the demonstrations. We implemented a separate component called "RDF Data Service" for interfacing with the ontologies hosted on the triplestore. Below is a set of indicative semantic reasoning scenarios that the ontology will address.

Semantic reasoning scenario	Relevant PUCs
Infer border trespassing based on trespasser's location.	PUC1.1-1.8
Estimate target's speed and moving direction.	All PUCs
Estimate pollutant's speed expansion and moving direction.	PUC3.1
Estimate target's ETA in a designated hot zone.	PUC1.1-1.8, PUC3.1
Assess whether a target is a threat or not: this will depend on detected objects and activities (e.g. firearms, potentially illegal activities like smuggling etc.).	PUC1.1-1.8, PUC2.1
Infer the role of agents (e.g. humans) in detected activities; CISE defines specific roles (e.g. "*observer*", "*victim*", "*perpetrator*" etc.).	All PUCs
Infer the type of irregular activity; CISE defines specific types of irregular and illegal activities.	All PUCs
Assess the severity of an event or an action; CISE defines specific levels of severity.	All PUCs

T4.5: Risk models (M3-24), Lead: UoA

This task refers to the development of a risk model framework that allows the user to assess and be notified about certain risk conditions that take place in real-time. The framework is capable of continuously evaluating the current conditions and how a certain risk evolves over space and time. The risk model's main responsibility is to collect data from various sensors, performing calculations, and offering useful recommendations to the ROBORDER users about the UAV/Sensor infrastructure and potential means to detect/monitor the considered incident more accurately. In the first half of the project, we have developed a risk model framework based on existing best practices and methodologies adopted by end-user organisations. Specifically, we have developed a system fully aligned with the Common Integrated Risk Analysis Model (CIRAM) which is the official risk model methodology proposed and followed by FRONTEX for the assessment of border control related threats and risk factors. An OWL2 ontology has been developed to represent the CIRAM model. This ontology has been connected with a set of general-purpose forecasting models that are used for predicting future system states. The ROBORDER users are able to manage the

[11] http://www.eucise2020.eu/
[12] https://www.w3.org/OWL/
[13] https://ontotext.com/products/graphdb/
[14] https://www.w3.org/TR/rdf-sparql-query/

output of the risk models based on the real-time information stemming from the environment (e.g., sensor values). During the integration phase, the framework has been connected with the ROBORDER Dashboard by ensuring that its output can be properly consumed and be visualised in the Dashboard environment. As a next step, we plan to evaluate the use of pre-defined mitigation plans and policies that will be triggered and be provided to the users as potential recommended actions to alleviate the considered threats. Also, the system will be connected with real assets (e.g., sensors) and UxV resources.

T4.6: Visual analytics and decision support (M6-24), Lead: CERTH

The **Visual Analytics** module focuses on providing the operator with a visual overview of the situation based on data provided from the UXV, static radar and other analysis modules. It allows them to assess the threat levels and make operation decision based on such information. These visual overviews are to be informative and a variety of map and non-map based visualisations are being developed with bespoke designs based on the incoming data streams. Weather conditions and other environmental factors that may have an effect on the current situation will also be displayed to the operator to allow them to take these into consideration. Examples of the data which feed the visualisations include GDACS, in order to represent environmental alerts and data from the UAVs, such as the mission types and alert types.

Currently, the visual analytics module has mock ups of exemplar visualisations that will be provided during the testing exercises. A number of these visualisations have been prepared using mock and artificial data, ready for integration with the dashboard and other modules. A draft version of D4.2, which details more of what the visual analytics module can provide in detail, is also in preparation.

In addition, for the **decision support** module of T4.6, the respective module builds upon the RDF Data Service (see T4.4) and generates recommendations for the operators (e.g. "*intercept*", "*search*", "*detect*" etc.), possibly suggesting (re)allocations of assets and/or suggesting the intervention of local forces wherever appropriate. Since the semantic reasoning scenarios are still in progress, this component is still largely immature, but our aim is to automatically document decisions, as well as the steps performed in reaching those decisions, in order to enable users to share this documentation to prevent conflicting decisions and build upon past experience. Furthermore, the generated recommendations will be based on the severity of the incidents detected, which will be calculated again via semantic reasoning, and will be accompanied by an alert level (e.g. detection of injured humans will increase alert level) and the confidence levels of the detections (objects, activities, persons).

1.3.4.1 WP4 Risks

This section presents the current WP4 risks.

Work Package 4 Risks	
Risk 1	Absence of proper data format for specific UxV technologies in order to be exploited in the enhanced human-robot UI (e.g. Improper video streaming format). The risk could be decreased by ensuring the correct format and/or using standards for such occasions.
Risk 2	Unsuccessful integration of the mission planner to the main operator interface-It was addressed during the first evaluation tests. The module was successfully integrated. Its proper execution remains to be evaluated in real operation scenarios.
Risk 3	Undefinable and/or faulty UxV positions could be used as the input of the resource controller, which could be a past record. This case could be a result of an increased network latency due to bad connection and/or high amount of data transmission. The risk will be mitigated by ensuring that the necessary resources are available.

Risk 4	Insufficient feedback from the PUC responsible in order to setup the semantic models properly. Bilateral contacts and discussions will assist to mitigate such risks.
Risk 5	Insufficient feedback from the end-users to identify what type of risk assessment models they exploit. Bilateral contacts will assist towards decreasing this risk.
Risk 6	Low accuracy rates from the identification modules of WP3. This risk could result to faulty outcomes from semantic-related modules (reasoning, decision support etc.). Its effects could be constrained by applying specific risk assessments in WP3 which are foreseen.

Table 8 – Work Package 4 Risks

1.3.5 Work Package 5

Work package number	WP5	**Start month**	1	**End month**	34
Work package title	Integration of ROBORDER platform for the remote assessment of border threats				
Lead partner	TEK-AS				
Contributing partners	CERTH, FHR, EASS, VTT, EVERIS, PSNI, GNR, CMRE, ORFK, ROB, SPP, ELTM, HMOD, CENTRIC, APL, OMST, BDI, Copting, UoA, CSEM, CNIT, MJ, CPT, RBP				

The objective Work Package 5 is to plan the technological roadmap and design the architecture based on user requirements and integrate the developed technical artefacts in previous WPs, namely WP2, WP3 and WP4.

The following section reports the advancements that have been performed for the corresponding WP5 tasks, as well as the current status of their implementation. The analysis is provided per task below.

T5.1: Technical system requirements and architecture (M1-12), Lead: TEK-AS

Task 5.1 was responsible for the definition of: (i) technological roadmap for the development of the ROBORDER system; and (ii) system architecture. The task has been already completed, and the work carried out under its scope was reported in two deliverables, namely: D5.1 and D5.2.

Technological Roadmap:

The design of the technological roadmap for the ROBORDER system was reported in D5.1. Initially, the involved partners started by describing and analysing several standard approaches for the development of a technological roadmap; moreover, it was decided that a 'multiple layer' approach would be adopted for the development of the ROBORDER system technological roadmap (as reported in Section 2 of D5.1) – this approach comprises three distinct layers: (i) technology / skills / competences / resources; (ii) product / service / capability / systems; (iii) business / market.

In addition to it, an initial draft of the high level architecture was provided (Section 3 of D5.1), alongside with a first assessment made with the consortium partners in order to catalogue the list of elements brought by these to be part of the whole ROBORDER system, divided into the following categories: (i) unmanned assets and additional platforms; (ii) sensors; and (iii) hardware and software modules (as reported in Sections 4, 5 and 6, respectively). Per element, several aspects beyond the main characteristics were assessed, namely: (i) payload information – if applicable; (ii) foreseen use in ROBORDER; (iii) foreseen changes within the scope of ROBORDER; (iv) technical infrastructure requirements and specifications; and (v) the timeline for integration and use within the ROBORDER project.

Ultimately, in Section 7 of D5.1, the project time line and respective milestones were reported, in which the major technical developments were identified and presented in terms of the expected time line to be delivered. It was also concluded that the ROBORDER system would be achieved through a gradual evolution of each asset/module/component developments, which is directly linked to the development activities envisioned for WP2, 3 and 4, integration activities of WP5 and, ultimately, the testing, demonstrations and system evaluation activities of WP6.

Technical system requirements and architecture:
In terms of the system architecture, its definition and related background work was reported in D5.2. The design approach for the definition of the architecture comprised the following: (i) analysis on the first version of the end-user requirements that were reported in initial version of D1.1 (see Section 2.2 of D5.2 for more details); (ii) an assessment on the existing architecture and data models (see Table 9 and Section 2.3 of D5.2); and (iii) a trade-off analysis on these architecture models in order to identify which were the most suitable to be used as the baseline for ROBORDER system architecture.

Name	Acronym	Section (D5.2)
ASTM Standard Guide for UUV Autonomy and Control	ASTM F2541-06	2.3.1
IEEE POSIX Open Systems Environment Reference Model	POSIX	2.3.2
NATO Multi-Domain Control Station	**NATO MDCS**	**2.3.3**
SAE Aerospace Generic Open Architecture Framework	GOA	2.3.4
SAE Architecture Framework for Unmanned Systems	AFUS	2.3.5
UK MoD Generic Vehicle Architecture	GVA	2.3.6
UK MoD Autonomous Platform Exploitation	MAPLE	2.3.7

Table 9 – Surveyed architectures / data models

After the trade-off analysis of the above presented architectures, the consortium made the conclusion that the best candidate was the under development NATO Multi Domain Control Station (MDCS). From the analysis performed, this model was seen as a good candidate due to its favourable characteristics in terms of design for interoperability, maintainability and extensibility, as well as for its modularity and allowance for the use of open standards.

Moreover, the consortium started defining technical requirements for the system: (i) functional and (ii) non-functional technical requirements – these were reported in Section 3 of D5.2. In addition to it, the high level operational concept and the proposal for the user's interface was also provided in this section of D5.2.

As for the Software architecture for the ROBORDER system, Section 4 of D5.2 comprised its description in terms of methodology, logical architecture, definition of the several layers, its deployment, catalogue of services to be integrated and standards and conventions. In terms of the logical architecture (see Figure 33), the following six layers were defined:

- **Interaction layer**: it refers to the hardware architecture (shown in the bottom of the scheme) and it deals with the pre-processed information and directly feed processed data into the 'Processed Data Repository'.
- **Interoperability layer**: it offers the specification and the tools to permit a standard and protocol-agnostic communication between the multiple UxV assets and the software platform (i.e. the translation of proprietary communication protocols into the ROBORDER Data Model, and *vice-versa*).
- **Persistence layer**: it refers to the storage of all data required in the ROBORDER System.

- **Integration layer**: it contains all the functionalities provided by the technical partners through their specific SW modules, and it is responsible for their integration within the ROBORDER System.
- **Interaction layer**: it offers the User Interface (UI) for the user to interact with the ROBORDER System, as well as some additional services that are related with the Mission (e.g. Mission Editor, Mission Dashboard, Mixed reality robot control, etc.).
- **Application layer**: it includes all the pilot applications that will be used during the project for testing/demonstration purposes.

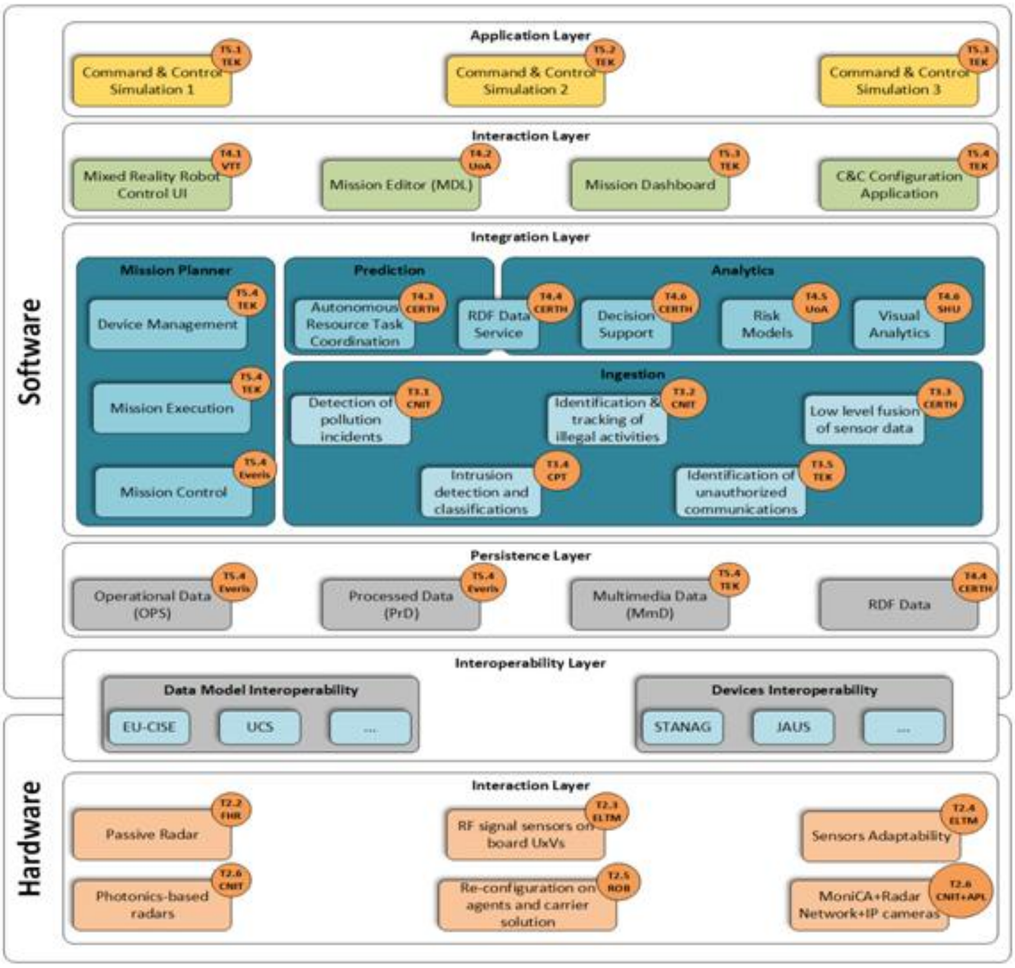

Figure 33 – ROBORDER system: logical architecture

On the other hand, for the preliminary version Hardware architecture of the ROBORDER system, the following scheme (see Figure 34) was prepared for its representation – this was addressed with more detail in Section 5 of D5.2.

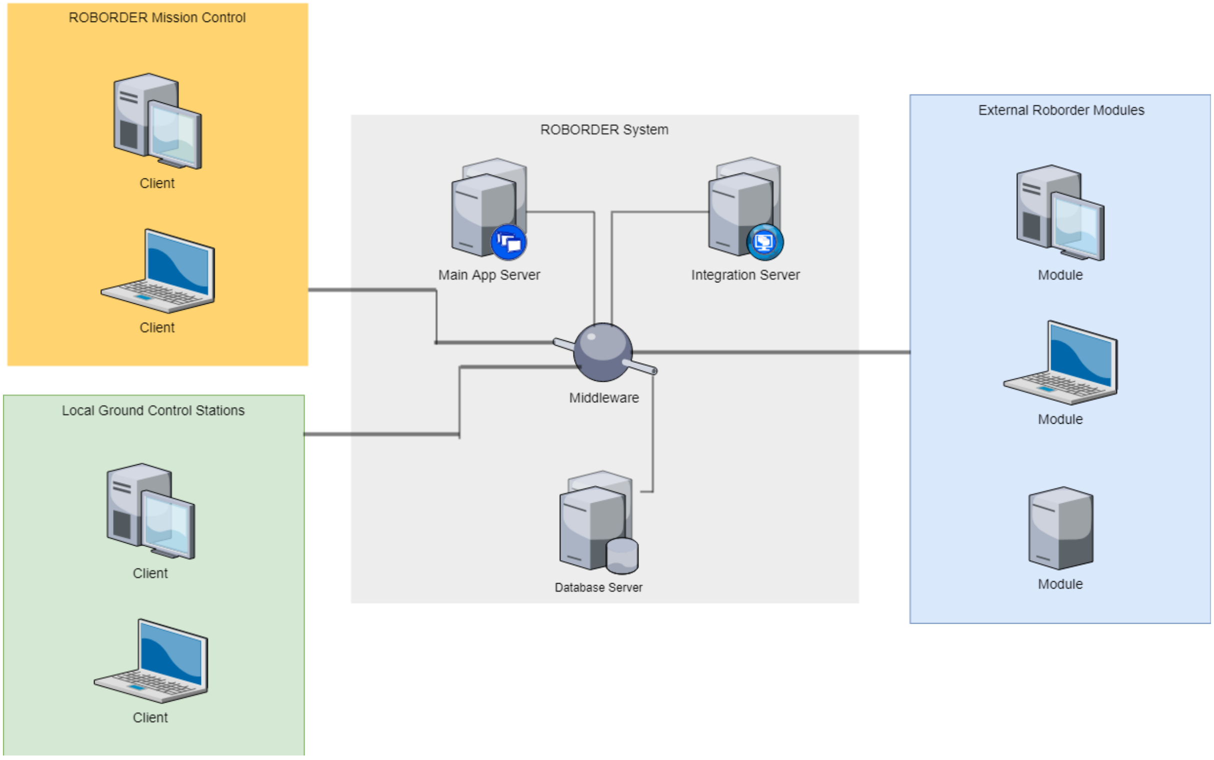

Figure 34 – ROBORDER system preliminary hardware architecture

The following can be verified from the above Figure:

- ROBORDER System users on the upper side to the left, within an orange box;
- Asset providers using their own software performing a mission on the lower side to the left, contained in the green box;
- Some external module providers that interact with the system on the right side, contained in a blue box;
- The ROBORDER System itself on the center, contained in a grey box.

In terms of middleware, as reported in D5.2, it was decided to be further explored only in the second half of the project.

Ultimately, under the scope of T5.1, the definition of the data model and interfaces was addressed (this was dully reported in Sections 6 and 7 of D5.2). With respect to the data model (for more details, please see Section 6 of D5.2), it was defined by using as its main baseline the data model from NATO NIAG SG 202. From its analysis, two specific data models were chosen as the starting point, namely: (i) the SAE UCS 3.4 Data Model (as suggested in NIAG SG 202 for aerial platforms); and (ii) the EUCISE 2020 Data Model. The defined approach comprises the following steps:

- Identification of both: (i) candidate baseline Data Models; and (ii) the required messages per platform and/or service to be integrated within the ROBORDER System;
- Analysis on the baseline Data Models in order to identify potential gaps and missing entries/structures (based on the identification mentioned in the 1st bullet);

- Enrichment of the baseline Data Model in order to achieve a fully interoperable ROBORDER Data Model that enables the exchange of information between all UxVs and services with the ROBORDER System.

In terms of the interface between both assets (UxVs) and the ROBORDER System, as well as services and the ROBORDER System, the proper communication interfaces were defined (as presented in Section 4 of D2.1). These interfaces were decided to be made through protocol translators (adaptors), pieces of software responsible for translating all the messages to be exchanged from the proprietary communication protocols (e.g. STANAG4586, MAVLINK, ROS, IMC JANUS, JAUS, etc.) into the ROBORDER Data Model and *vice-versa*. The same approach was followed for the integration of software modules.

T5.2: Software integration (M10-33), Lead: Everis

Task T5.2 is the task that comprises all the integration activities related with the software part of the ROBORDER system. Under this task, the following was already performed by the involved technical partners:

- Preparation of the messaging structures for the connection with the server (i.e. 'ConnectRequest');
- Registration of each asset (UxV) and modules/services;
- Delivery of telemetry messages (i.e. 'KinematicPlatformType') for the case of assets (UxVs);
- Query to the server in order to obtain information regarding the available assets (i.e. 'QueryRequest');
- Subscription of a desired asset (i.e. 'SubscribeRequest');
- Validation of the before mentioned steps for each asset and/or service provider.

T5.3: Hardware integration (M10-33), Lead: TEK-AS

T5.3 is the task that includes all the integration activities related with the hardware part of the ROBORDER system. For this task, the work already performed is summarized in the following bullets:

- Each technical partner executed its service or simulated asset in separated computers;
- The physical machine where the application server and the ROBORDER user interface were running was physically separated;
- The two first bullets enabled the consortium to simulate the Docker environment;
- Ultimately, EVERIS prepared a physical machine for the Dockers that will be further used in the next tests so that the consortium can simulate the final environment where the ROBORDER system will be deployed.

T5.4: ROBORDER System integration (M11-34), Lead: TEK-AS

Task T5.4 comprises the system integration related activities. Under the scope of this task, the 1st Prototype of the ROBORDER system was developed, and it was reported in D5.3.
The 1st integrated prototype of ROBORDER was prepared and tested in M18 of the project, with the main goals of:

1. Test the pre-defined ROBORDER System architecture including the testing of: (i) translators for platform (UxVs) integrators; (ii) ability of the different SW services/modules to interface with the system.

2. Based on the tests results, validate the pre-defined ROBORDER System architecture.
3. Identify the required next steps towards 2nd and Final Prototypes (to be delivered, respectively, at M26 and M34).

In that sense, D5.3 contains an initial overview (see Section 2 of D5.3) on several aspects including: (i) high level architecture (see Figure 35); (ii) logical (SW) and hardware architecture; (iii) data model and interfaces.

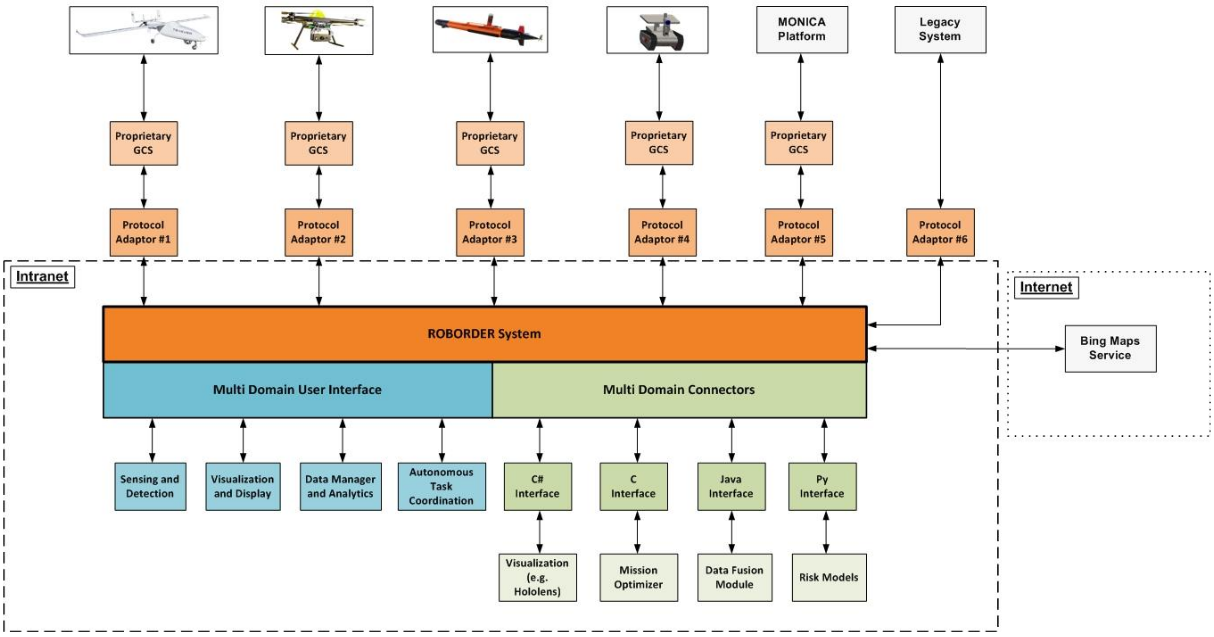

Figure 35 – ROBORDER system high level architecture

Moreover, D5.3 has a summary on all UxV platforms, services/modules and additional components that will be part of the ROBORDER system – these were identified and dully described in Section 3 of D5.3.

In addition, the 1st prototype was then described in terms of: (i) its high level architecture (please see Figure 36), (ii) the system itself including the user interface (see Figure 37), and (iii) the current version of data model – these aspects were described in detail in Section 4 of D5.3. In terms of the architecture for the 1st prototype, it was designed to be as close as possible to the final planned architecture, having into account the implementation status of the global project.

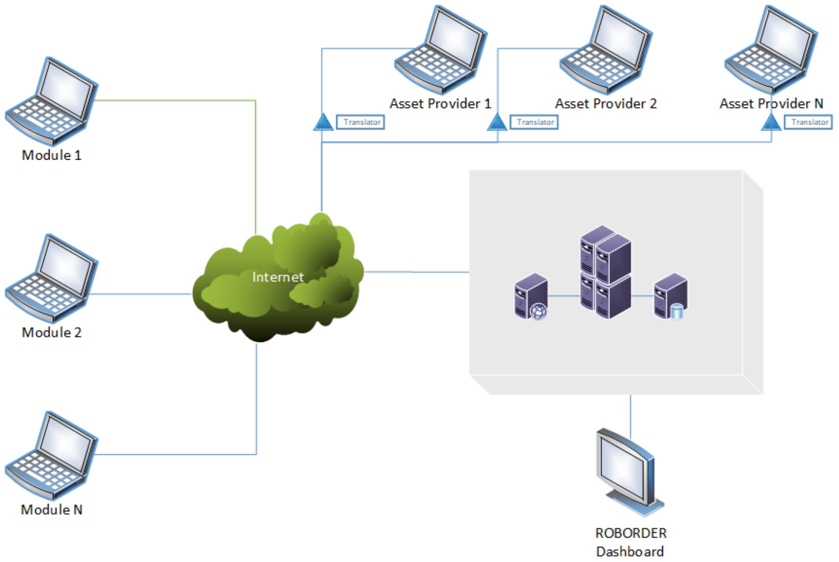

Figure 36 – 1st Prototype of ROBORDER System: High-level Architecture

The four components of the 1st prototype were the following:

- Application server, where all computational work regarding information coming from modules and assets would be processed and managed;
- Database server, where information regarding the connected assets, payloads, services and processed data would be stored;
- Communication layer, in charge of managing and processing all connections coming from external components (i.e. assets or services);
- Dashboard, where all the information mentioned before is to be displayed to one or more users.

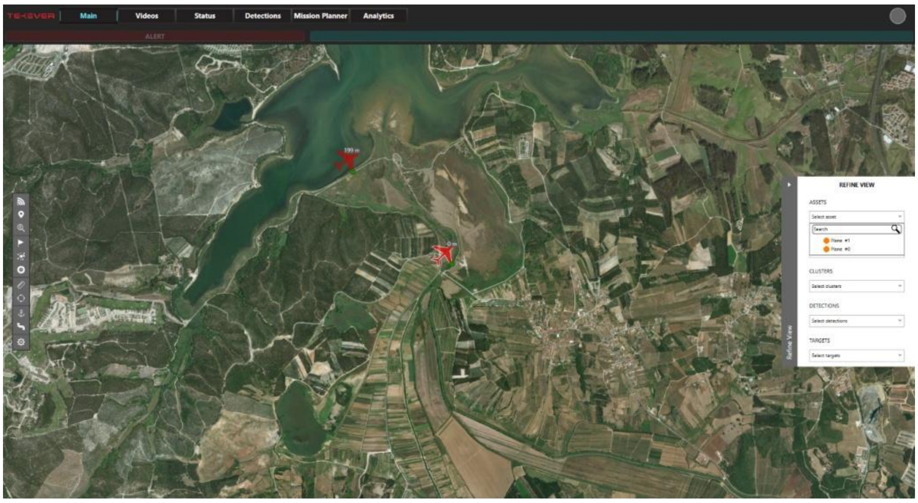

Figure 37 – 1st Prototype of ROBORDER System: 'Main' Tab of Dashboard

The data model and the respective approach for the interface with the system were described with detail in Section 4.3.2 of D5.3.

Under the scope of this task, some of the partners defined KPIs applicable to the 1st prototype version of their services/modules, which were reported in Section 5.2.1 of D5.3. In addition to it, a consortium meeting was held in order to perform the integration activities with the partners (see Section 5.3 of D5.3) – from this meeting, as well as remote integration activities held with the partners that couldn't participate in the meeting, the consortium achieved successful results regarding the integration with the 1st prototype (for more information see Section 5.4 of D5.3): all service/module providers were able to test the initial messages; also, the interaction between the ROBORDER system and assets were tested for the case of UAVs (TEK-AS), UGVs (ROB) and USVs/UUVs (OMST). As conclusion, the 1st prototype enabled the consortium to achieve the proposed goals for this version of the system, ensuring that the architecture defined is validated and that the system can accommodate different types of UxVs, thus validating the multi-domain characteristic of the system.

1.3.5.1 WP5 Risks

This section presents the current WP5 risks.

Work Package 5 Risks	
Risk 1	Lack of information regarding some of the architecture models to be used as a reference for the conceptualization of the ROBORDER System architecture. • Mitigation: make use of consortium partners' expertise in this technical field; exchange information with other on-going projects tackling the same topic.
Risk 2	Failure of scientific integration. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.
Risk 3	The planned approach is not successful because of new technical developments that render it obsolete. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.
Risk 4	Ill implemented interoperability interfaces may limit the impact of ROBORDER. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.
Risk 5	Lack of partners' contribution to the reporting activities of WP5. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.

Table 10 – Work Package 5 Risks

1.3.6 Work Package 6

Work package number	WP6	**Start month**	1	**End month**	36
Work package title	Demonstration and evaluation				
Lead partner	CMRE				
Contributing partners	TEK-AS, CERTH, FHR, EASS, VTT, EVERIS, PSNI, GNR, CMRE, ORFK, ROB, SPP, ELTM, HMOD, CENTRIC, APL, OMST, BDI, Copting, UoA, CSEM, CNIT, MJ, RBP				

Work Package 6 objective is to evaluate the platform developed within the ROBORDER framework and train the border authorities and LEAs for using it. In the context of the Work Package 6 the following tasks have started:

- **End-user evaluation plans and methodology:** CMRE, with the collaboration of the Consortium, has developed a methodology for the evaluation of the ROBORDER Platform performances as a whole and of its single functional components. The methodology will be applied both to simulated testbeds for performance evaluation and to live demonstrations. It is articulated in four phases: Define parameters of the evaluation; design the methods for the evaluation; collect evidence; report and make decisions. A preliminary wide spectrum list of KPIs was identified for D6.1 in order to evaluate ROBORDER Platform performances. This KPI list has been recently updated based on the systems requirements developed for Task T1.1 and reported in D6.3.

An Action Plan for each Pilot Use Case (PUC) has been developed to identify the steps or tasks necessary to ensure a successful development of the ROBORDER Platform for each evaluation cycle.

- **Operational training**: ORKF has defined a pilot training with involvement of border security and aviation security experts; currently the procurement of this pilot training is in progress. During the pilot training the curricula and training structure will be according to the concept of operations of the ROBORDER system. The training will be a three-weeks long blended training, starting with an e-learning phase, commencing with simulator training and ending with an exercise and test flight.
- **Preparation and implementation of test plans as simulated exercises:** CMRE, following the DSEEP methodology (IEEE1730 standard and STANAG 4603), has designed the simulated test bed capability. Until this moment, all the phases of the Simulation capability design have been performed, namely: user needs and objectives identification, development of scenarios in cooperation with ROBORDER end users, the related conceptual modelling activities and requirements development, the design of the federation of simulators and the development of the Federation Object Model reflecting the simulation relevant datatypes of the Data Model adopted for ROBORDER. Currently the implementations activities have begun.

1.3.6.1 WP6 Risks

This section presents the current WP6 risks. It is worth to mention that a risk matrix specific for the simulation based testbed has been provided in D6.3 in Section 3.1.
The following risks identified are about the organization of the Demonstrations and operational tests, responding to tasks T6.4 and T6.5 - those tasks will start in M19.

Work Package 6 Risks	
Risk 1	Lack of participation of ROBORDER Partners in the operational tests and demonstrations. • Mitigation: thorough involvement of partners.
Risk 2	Missing authorization to deploy autonomous vehicles tests locations. • Mitigation: clarify requirements for the participation and deadlines.
Risk 3	Lack of resources to carry out demos will limit the impact and acceptance of ROBORDER. • Mitigation: a shift of effort and budget between partners and WP will be discussed by the PMB.
Risk 4	Impossible to collect metrics during the Live tests. • Mitigation: Definition of the metrics to collect during the live tests at an early stage of the tests planning.
Risk 5	ROBORDER assets not ready to perform the tests. • Mitigation: perform a second integration test with real data exchange.
Risk 6	Impossibility to analyse the data collected to evaluate the tests for security issues. • Mitigation: clarify security requirements for the management of data.
Risk 7	Public procurement will not succeed. • In case the public procurement will not succeed (there will be no bids, or all bids will be over the budget) then the ORFK will make a written notification on this to the National Procurement Authority and will ask for permission to purchase the training from project partners or from third parties without procurement (quotation still needed).
Risk 8	Public procurement will not be finished on time. • In case the public procurement will be successful, but due to time constraints the delivery can't be performed before the pilot deployment, then

	ORFK will contact UxV operators or ask partners to provide operators for the UxVs for the trial.
Risk 9	Not enough ROBORDER craft will be available for training. • In case of insufficient numbers of low number of available ROBORDER UxVs for the training, then ORFK will rent civilian UxVs with similar flight parameters (e.g. fixed wing, rotary wing, in size, weight, etc.). Deployment of authorized own (ORFK) crafts for project purposes are not permitted.

Table 11 – Work Package 6 Risks

1.3.7 Work Package 7

Work package number	WP7	**Start month**	1	**End month**	36
Work package title	Dissemination and exploitation				
Lead partner	EVERIS				
Contributing partners	TEK-AS, CERTH, FHR, EASS, VTT, PSNI, GNR, CMRE, ORFK, ROB, SPP, ELTM, HMOD, CENTRIC, APL, OMST, BDI, Copting, UoA, CSEM, CNIT, MJ, CPT, RBP				

Work Package 7 main objective is to disseminate and exploit the results from ROBORDER project. Its main goal is to ensure all relevant market actors' awareness about the project, its progress and the main results achieved, and exploration of possible exploitation opportunities within academia, industry, SMEs and end-users.

The advancement in this WP is presented per task below.

T7.1: Dissemination and events organisation (M1-36), Lead: HMOD

This task presents the dissemination and the communication strategy along with all the relevant activities report that were performed during the first 18 months of the project.

Furthermore, the related synergies, projects and initiatives, such as other close related EU projects and participations in scientific Journals and Conferences, as well as Publications and Presentations from ROBORDER members are presented. In D7.4 'Mid-Term Dissemination Reports', the participation of the ROBORDER consortium in events, conferences and workshops, as well as in meetings with stakeholders and other user groups was reported. Next table summarizes the whole effort spent by the consortium in dissemination activities for the first season of the project.

Type of Activity	Number of Partners	Number of Activities
Website	3	3
Social Media	3	4
Intranet	2	2
Mailing	3	6
Article	2	3
Conference	2	9
Workshop	1	1
Dissemination Material	2	2
Presentation	4	14
Exhibition	1	1
Information	1	1
Publication	1	1
Post Graduate Thesis	1	2
Synergy	1	1
Journal	1	4
Conference Papers	1	18

Event	1	1
Poster	1	1

Table 12 – Summary of dissemination activities that occurred during the 1st half of ROBORDER

T7.2: Communication (M1-36), Lead: CERTH

The task aims at developing the proper dissemination material and spreading the acquired knowledge during and after the period of the project's development. During the first trimester of the project, the website along with other dissemination material were developed. More specific, the website (Figure 38) was developed in order to comprise an interactive platform and present the main vision, objectives and technological advancements of the final ROBORDER framework to a wider audience. The content of the website is updated regularly in order to reflect the progress that is achieved. In general, a visitor could be informed about the objectives, the structure, the consortium and relevant news as well as download the extra dissemination materials.

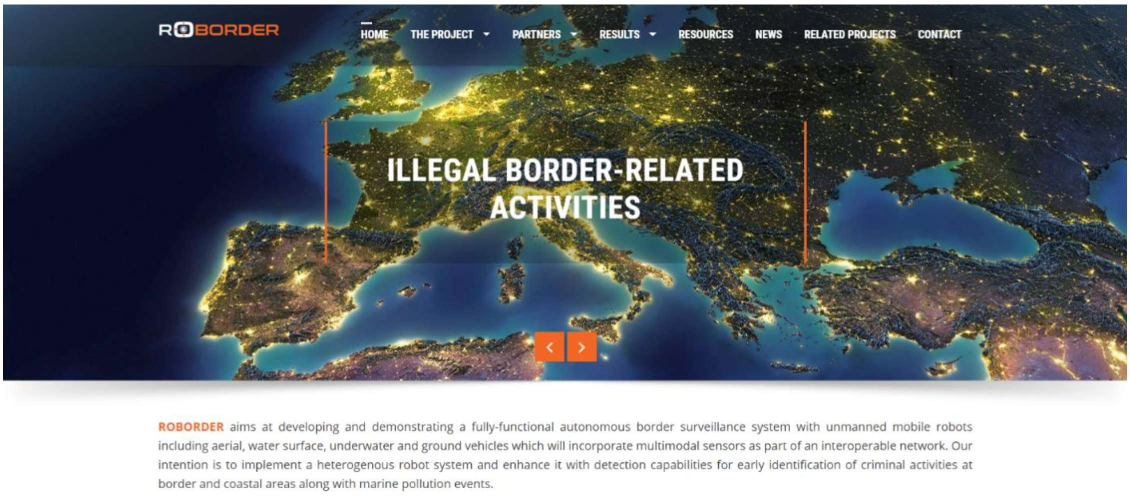

Figure 38 – Home page of the ROBORDER website

In addition, the communication kit that has been designed is and could be exploited to assist towards the dissemination of the projects results. The corresponding files will be used in workshops and conferences where project members can participate. All the materials include concrete descriptions of the project's main concepts and targeted information so that the material could be attractive to a wider audience, meaning scientists and multiple stakeholders. The communication kit involves an overall presentation (Figure 39a), a leaflet (Figure 39b) and a factsheet (Figure 39c). Finally, the basic dissemination means in the context of ROBORDER were described and analyzed in the deliverable D7.2 which was submitted at the 3rd month of the project.

Figure 39 – Communication kit: (a) Presentation; (b) Leaflet; and (c) Factsheet.

T7.3: Standardisation and collaboration with other projects (M1-36), Lead: CMRE

Until this moment the ROBORDER project has focused its efforts in the standardisation of the protocols and data types used within the consortium. Once the ROBORDER architecture and prototypes reach a more mature stage, it will be possible to search for collaborations and synergies with other projects.
For the moment the consortium has selected four different communication protocols for the interoperability of the assets with ROBORDER platform architecture: STANAG 4586, MAVLINK, ROS and IMC. Furthermore, all the partners have started working in the extension of a data model based on the UCS 3.4.
These two approaches are going to facilitate the standardisation and collaboration with other partners in the future.

T7.4: Market Analysis (M3-14), Lead: Everis

The main objective of this task is to analyse the potential market for the different outcomes of the project. The created methodology for market analysis by everis covered all the most relevant items, such as characterisation and determination of market actors, external analysis from the perspective of environment, competition and trends, analysis of regulations associated with sector and products, and the main drivers for the demand and potential market, including volume and growth trends. All the main findings and conclusions of 14 months research and analysis concluded that there is a high potential for the ROBORDER project results.

T7.5: Business model (M14-36), Lead: Everis

The main objective of this task is to plan the definition of initial business plans to support the commercial exploitation. The information gathering and exchange on commercial aspects and business has been already started by everis, and the preliminary results have been presented in the D7.3, covering the key partners, key activities and key resources for the delivery of ROBORDER results to the market. The workshop for business model definition for ROBORDER project has been discussed and should be organised in the near time for ROBORDER commercial exploitation.

T7.6: Exploitation and long-term sustainability plan (M14-36), Lead: TEK-AS

This task refers to the development of an innovation and exploitation plan, where all expected and eventual ROBORDER outcomes are fully documented. This plan ensures that all identified innovative elements of the ROBORDER project are going to be fully sustained after the end of the project. D7.3 presents the preliminary everis proposed version of the exploitation and long-term sustainability plan for ROBORDER. The proposed Exploitation and long term sustainability framework covers external environment, business model, implementation roadmap, IPR and CA and managements related issues, Risk analysis and individual exploitation plans of consortium members. The overall view is presented in the picture below.

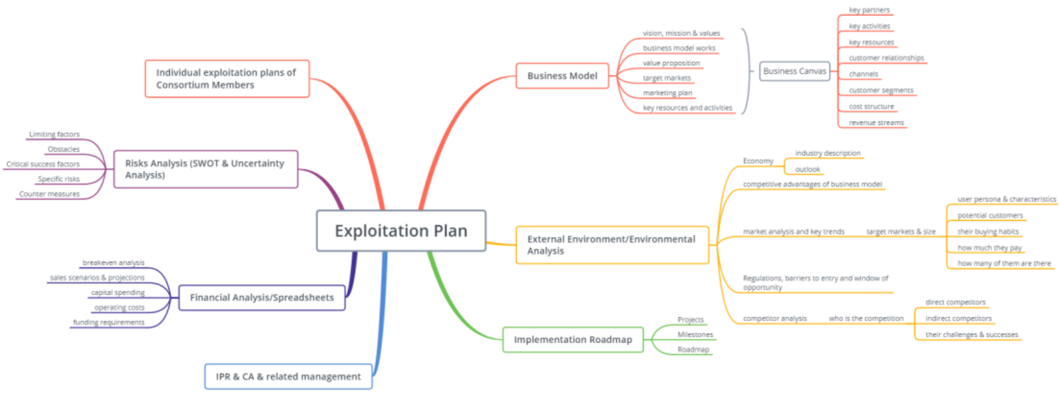

Figure 40 – Schematic on the overall view of the Exploitation Plan

1.3.7.1 WP7 Risks

This section presents the current WP7 risks.

Work Package 7 Risks	
Risk 1	Lack of participation of ROBORDER Partners in the creation and contribution of dissemination activities. • Mitigation: thorough involvement of partners.
Risk 2	Missing substantial contribution to communication activities. • Mitigation: clarify requirements for the participation and deadlines, and additional motivation measures.
Risk 3	Lack of resources from the partners to contribute to the market analysis, business model and exploitation plans. • Mitigation: a shift of effort and budget between partners and WP could be discussed by the PMB, and the revision of effort forecasted/charged to results ratio of partners input within the WP.
Risk 4	Impossible to collect the data for financial exploitation of ROBORDER from all the partners. • Mitigation: organisation of the workshop on business plan with mandatory attendance and ROBORDER exploitation and re-definition of the metrics to collect during the workshop on financial exploitation.
Risk 5	The delay of WP7 deliverables due to dependency on other WPs' delivery and its delay. • Mitigation: perform additional research and try to reduce dependencies.
Risk 6	Impossibility to collect data from project partners for security issues. • Mitigation: clearly identify the needed data as missing due to security issues within deliverables and to try to clarify security requirements for the management of data.

Table 13 – Work Package 7 Risks

1.3.8 Work Package 8

Work package number	WP8	Start month	1	End month	36
Work package title	Project management				
Lead partner	TEK-AS				
Contributing partners	CERTH				

Work Package 8 deals with all of the management work that is transversal to the technical achievements reached in the remaining work packages. In this sense, it is important to state that under this work package lays three major responsibilities:

- **Project management (from Technical point of view)** – TEKEVER AS, alongside with the Scientific and Technical Manager (STM) - Mr. Elias Kosmatopoulos from CERTH, have been involved since the kick-off of the project in its technical management, which include the coordination of multi-work package activities, as facilitator of dialogue, quality enforcer and liaison to external entities to whom ROBODER provides or requests information (e.g. NATO MDCS working group). Under this responsibility, the coordinator has organized, together with the hosting partners, the Kick-Off meeting – Lisbon, PT; 3 Technical Meetings – Budapest, HU; Thessaloniki, GR; and Sheffield, UK; and ultimately, the 1st Prototype Internal Meeting – Lisbon, PT.
- **Project administration, reporting and financial management –** the coordinator, TEKEVER AS, has been responsible for liaising with the EC Project Officer, Mr. Francesco Lorubbio (previously, with Mr. Paolo Salieri), and was responsible in the beginning of the project to place into force a Consortium Agreement (CA). Moreover, TEKEVER AS is also responsible for the collection of all administrative data, cost and spent effort reports and the distribution of EU funds to beneficiaries. It has also been coordinating all the amendments to the Grant Agreement (GA) due to changes in legal constitutions of one of the beneficiaries;
- **Quality assurance and risk management –** as the coordinator, TEKEVER AS has been responsible for dealing with the quality assurance and risk management of the ROBORDER project. In that sense, TEKEVER AS was in charge of establishing documentation, reporting and following the communication procedures. Also, the coordinator was responsible during this period to ensure that the desired quality and timelines were met – in close cooperation with the STM and the Innovation Manager (IM). Ultimately, as the coordinator, TEKEVER AS was in charge of detecting project risks and to take the respective corrective actions as necessary – the project risks identified in the proposal phase, alongside with the possible risk mitigation / decision for closure or change are covered in Section 1.2.2 of this report, while the specific risks of each WP are presented in the sub-sections of Section 1.3 of this report.
- **Management of confidential information –** under T8.4, TEKEVER AS created the Data Management Plan (D8.2) in the initial stage of the project, and was responsible to ensure the proper management of confidential information that was used within the project.

So far, two deliverables were prepared and submitted under this WP, namely: D8.1 (Project management and quality assurance plan) and D8.2 (Self-assessment and data management plan V1). In addition to it, the first draft of D8.3 (Mid-term review and progress report) is now presented, and will be completed after the mid-term review that will be held in Brussels (December 2018).

1.3.8.1 WP8 Risks

This section presents the current WP8 risks.

Work Package 8 Risks	
Risk 1	Partner drops out of the project. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.
Risk 2	Impact of Brexit in the project. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.
Risk 3	Delays in the distribution of funds may result in partners stopping their technical contribution and hence in delays to the project execution. • Mitigation: presented in Section 1.2.2 (Risk Management) of this document.

Table 14 – Work Package 8 Risks

1.3.9 Work Package 9

Work package number	WP11	Start month	1	End month	36
Work package title	Ethics requirements				
Lead partner	TEK-AS				
Contributing partners	-				

The current section aims at summarizing all the work involved in ROBORDER's continuous ethical screening, performed until the end of October 2018. The ethical screening under the scope of ROBORDER focuses on several domains:

- **Research with Humans** – in view of the fact that ROBORDER will perform demonstration exercises, suitable copies of ethics approvals for this "research with humans" will be obtained and the due corroboration will be also send to the Commission through D9.1. As a result, the D9.1 is focused essentially in the latest H2020 Ethical guidelines and its recommendations, so the entire Consortium acts in accordance with the compulsory procedures. For D9.1 the Partner VTT, built a meticulous informed consent along with its description complying with the due regulations. In addition, TEKEVER performed a H2020 'Ethics Issue Checklist' regarding the ROBORDER "research with humans" and the appraisal outcomes were that: a) The research DOES involve human participants (but not their identification); b) There are NO persons unable to give informed consents; c) There are NO vulnerable individuals or groups; d) There are NO children/minors; e) There are NO patients; f) The research does NOT involve physical interventions on the study participants; g) The research does NOT involve invasive techniques; h) The research does NOT involve collection of biological samples.

- **National Data Protection Authorities' authorizations/confirmations** – opinion or confirmation by the competent Institutional Data Protection Officer and/or authorisation or notification by the National Data Protection Authority is, on a regular basis, unavoidable in most of the projects involving image, video and / or audio acquisition. Since ROBORDER will acquire images throughout its execution, it is not an exception when it comes to the Protection of Personal Data of the people involved. Hence, D9.2 tackles this issue approaching the highest European Union ethical guidelines, privacy and data protection laws and principles to reduce potential ethical / privacy concerns, mainly the Regulation 2016/679 (General Data Protection

Regulation). As a main goal, D9.2 intended to present to the European Commission and to the ROBORDER Consortium members the ethical framework applicable to the project as well as a template (developed by TEKEVER) for a notification / authorisation request letter to be sent to the National Data Protection Authorities prior to the execution of any activities involving imagery or audio acquisition. The actual permits will be reported on the final project report.

- **Operations with UAVs** – since the demonstration exercises will take place, at least, in Greece, Portugal and Hungary, approval for the operation of UAVs will be requested to the Hellenic Civil Aviation Authority (HCAA - ΥΠΑ), to the National Institute of Civil Aviation of Portugal (ANAC), and to the Hungarian Civil Aviation Authority (CAA-HU). Compulsory procedures for obtaining the appropriate flight authorizations and the latest regulations are addressed in D9.4. Regulations such as the European Parliament and of the council on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, will also be shared with the consortium' partners.

- **Dual use implications** – given that we have a dedicated topic on operations with UAVs, we have to approach its dual use implication: as soon as we have an item/technology that can fall in erroneous hands (in a hypothetical situation), moreover, that could be misused by modifying and tailoring it in such a way that could be converted into a dual use item/technology, several ethical issues are instantaneously raised, essentially regarding the environment and humanity safety in addition to the respect of human rights. Therefore, deliverable 9.5 is focused in potential dual use implications of the project, appropriate risk-mitigation strategies and in the due ethics approvals. A clarification of the dual use and misuse concepts was made, H2020 guidelines and EU regulations were explained and the appropriate ethics issue checklist was carried out. Both 'Ethics Issue Checklists' in the section 4 of D9.5, as well as cautious appraisals from the consortium Security and Ethical Advisory Boards where steps to avoid any potential misuse and appropriate safeguards to cover security risks and training for researchers, were carefully thought. Furthermore, the consortium involves human rights experts, in order to make sure that ROBORDER' research acts in accordance with all ethics and principles. In cooperation, they identified risks and devise strategies when required to diminish and deal with likely risks. It is important to state that both Boards are composed by seasoned professional in ethics, compliance and in the protection of classified material and matters of National Security.

- **External Ethical Advisor** – WP9 has several deliverables fully dedicated to ethics requirements. However, in addition, the project coordinator, TEKEVER, has an ethical team supporting the monitoring activities within ROBORDER, and an External Ethical Advisor (EEA) that has been contracted and is currently proving guidance to the consortium. Mr. Reinhard W. Hutter is Technical Director of the Centre for European Security Strategies and has many years of technical and managerial experience, particularly in the security sector. He has extensive experience in ethics in security, namely on the new security challenges, including information operation, critical infrastructure protection and anti-terror strategies, acquired through the participation in several related national and EU projects. Hence, there is a final deliverable in WP9 (D9.6) which is a report by the EEA that has been submitted to the Commission along with this periodic report: During the last months the EEA evaluated the series of draft Deliverables of WP9: D9.1 to D9.5 and a template for systematic review of the deliverables was created. Comments from the EEA were done and registered. The individual review results were supported by a number of general notes that apply to all or a number of deliverables, and a suggested scheme for mapping of requirements was built. This was followed by a proposed systematic evaluation of the ROBORDER ethical implications, along the methodology discussed with the EEA. Ethical and societal evaluation was performed.

2 Annexes

ROBORDER					
	WP/Task name	Leader	Start Month	End Month	Duration
WP1	User requirements and pilot use cases	HMOD	M 1	M 28	28
T1.1	User requirements for border surveilance	HMOD	M 1	M 28	28
T1.2	Security requirements	BDI	M 1	M 28	28
T1.3	Ethical and legal requirements	EASS	M 1	M 28	28
T1.4	Design of the pilot use cases	HMOD	M 1	M 28	28
T1.5	Design of the concept of operations for the use cases	VTT	M 1	M 28	28
WP2	Adaptable sensing, robotics and communication technologies to operational and environmental needs	ELTM	M 1	M 24	24
T2.1	Hierarchical cloudlet based communication network architecture to support context-aware reliable and secure communications	TEK-AS	M 1	M 12	12
T2.2	Optimized passive radar on board UAVs and USVs	FHR	M 1	M 24	24
T2.3	Passive RF signal sensor on board UXVs	ELTM	M 1	M 24	24
T2.4	Optimization of sensors for a variety of situations and conditions	ELTM	M 1	M 24	24
T2.5	Re-configuration of agents and carrier and charging solutions to adapt to extreme and diverse weather and sea conditions	ROB	M 1	M 24	24
T2.6	Photonics-based radars interoperable with existing infrastructure	CNIT	M 3	M 24	22
WP3	Detection and identification of border-related threats	CNIT	M 1	M 24	24
T3.1	Detection of pollution incidents	CNIT	M 1	M 24	24
T3.2	Identification and tracking of illegal activities	CNIT	M 1	M 24	24
T3.3	Low level fusion of sensor data along with environmental and geographical	CERTH	M 1	M 24	24
T3.4	Detection and classification framework for recognising cyber and cyber-physical attacks	CPT	M 1	M 24	24
T3.5	Early identification and tracking of illegal communications using software defined RF transmission sensor	TEK-AS	M 3	M 24	22
WP4	Command and control unit functionalities	CERTH	M 3	M 24	22
T4.1	Novel Human-Robot interface, which exploits immersive 3D virtual reality environment and/or augmented reality interface	VTT	M 3	M 24	22
T4.2	DSL-based mission specification	UOA	M 3	M 24	22
T4.3	Resource controller - Adjustable, plug and play remote control..	CERTH	M 6	M 24	19
T4.4	CISE-compliant common representation model and semantic-based fusion	CERTH	M 3	M 24	22
T4.5	Risk models	UOA	M 3	M 24	22
T4.6	Visual analytics and decision support	CERTH	M 6	M 24	19
WP5	Integration of ROBORDER platform for the remote assessment of hazardous situations in border areas	TEK-AS	M 1	M 34	34
T5.1	Technical requirements and architecture	TEK-AS	M 1	M 12	12
T5.2	Software integration	EVERIS	M 10	M 33	24
T5.3	Hardware integration	TEK-AS	M 10	M 33	24
T5.4	ROBORDER System integration	TEK-AS	M 11	M 34	24
T5.5	System deployment and maintenance in testing environment	TEK-AS	M 18	M 34	17
WP6	Demonstration and evaluation	CMRE	M 1	M 36	36
T6.1	Creation of end-user evaluation plans and methodology based on requirements and use-case scenarios	CMRE	M 1	M 28	28
T6.2	Operator training	ORFK	M 5	M 36	32
T6.3	Preparation and implementation of test-plans as simulated exercises	CMRE	M 15	M 34	20
T6.4	Prototype Demonstration and Evaluation for polution and other incidences occurred in borders use case	GNR	M 19	M 36	18
T6.5	Prototype Demonstrationa and Evaluation for illegal activities and communications use case	ORFK	M 19	M 36	18
WP7	Dissemination and exploitation	EVERIS	M 1	M 36	36
T7.1	Dissemination plans and events organisation	HMOD	M 1	M 36	36
T7.2	Communication, web presence and promotional material	CERTH	M 1	M 36	36
T7.3	Standardization and collaboration with other projects and initiatives	CMRE	M 1	M 36	36
T7.4	Market analysis	EVERIS	M 3	M 14	12
T7.5	Business models	EVERIS	M 14	M 36	23
T7.6	Exploitation and long-term sustainability plan	TEK-AS	M 14	M 36	23
WP8	Project management and coordination	TEK-AS	M 1	M 36	36
T8.1	Project Management and Coordination	TEK-AS	M 1	M 36	36
T8.2	Project administration, reporting and financial management	TEK-AS	M 1	M 36	36
T8.3	Quality Assurance and Risk Management	TEK-AS	M 1	M 36	36
T8.4	Data management	TEK-AS	M 1	M 36	36
WP9	Ethics Requirements	TEK-AS	M 1	M 36	36
T9.1	Ethics Requirements	TEK-AS	M 1	M 36	36
	Milestones				

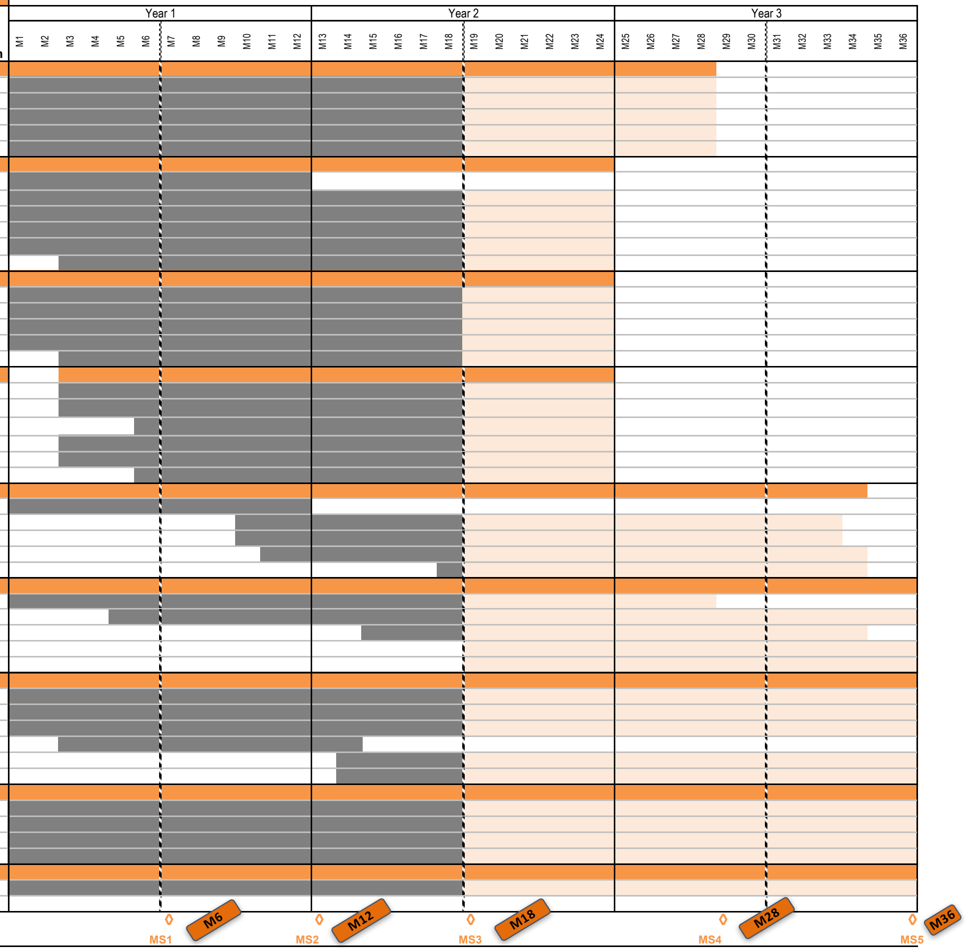

Figure 41 – ROBORDER Gantt chart with progress: Enlarged Version