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REPORT ON STANDARDS AND COLLABORATIONS

ROBORDER
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Abstract: This deliverable reports the ROBORDER activities concerning the use of (de facto) standards to enable the interoperability of all ROBORDER subsystems and third party elements that contribute to the multi-domain border security platform.
Collaborations with other projects are also included in this document. These facilitated project innovation, the exchange of knowledge and the application of best practices in the areas of security, surveillance and monitoring.
Standardisation and collaboration with other projects are carried out by most project partners and coordinated under Task T7.3. The ROBORDER standardisation and external collaborations activities are illustrated in this document with respect to their focus areas, domains, topics and types of activities, explaining their association with operational ROBORDER tasks. The data in support of this document have been prepared with the collaboration of the reference ROBORDER partners.

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Executive Summary

The ROBORDER project developed a multi-domain border security platform that integrates autonomous vehicles in land and sea border security scenarios. This platform required the integration of several project components that adopt and innovate cutting-edge technologies.

To facilitate the interoperability among the platform components, the ROBORDER consortium took on a wide standardisation effort. In addition, standards, guidelines and best practices have been applied to ensure the execution of UxV mission and their safe operations, to the development of software architectures and user interfaces and to ensure the protection of data and end-user privacy. Overall, the development and validation of ROBORDER adheres with 19 de facto standards and best practices, including:

- 7 information models for exchange and interoperability of maritime and border security data, data to multi-domain control stations and augmented reality devices, map tiles, and temporal information;
- 1 architectural model for interoperable automated machine-to-machine data exchange and Internet-of-Things (integration of networked devices) technologies;
- 1 architectural model and 2 best practices for interoperable simulations;
- 4 safety regulatory frameworks, including 3 for safe UxV mission operations;
- 1 regulation for data protection and privacy at European level;
- 1 guideline for architecture development;
- 1 Unmanned vehicles mission specification language;
- 1 User experience best practice.

23 standardisation activities were reported, including:

- 17 standard adoption and alignment activities;
- 4 standard enrichment and implementation activities;
- 1 standard modelling and implementation activity;
- the participation to 1 standard committee.

To facilitate the transfer of knowledge on key ROBORDER areas, especially surveillance, monitoring and security in multi-domain environments and the adoption of innovative technologies and approaches, ROBORDER partners collaborated with 20 other projects, including:

- 15 European Horizon 2020 projects;
- 2 European Defence Agency projects;
- 1 European Space Agency project;
- 1 European structural and Investment funds project;
- 1 Federal research project funded by the Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center.

These collaborations involved also extra-European countries (Israel and South-Korea), and covered the four domains of interest for border surveillance, i.e., sea, land, air, and underwater in the area of surveillance (52,9% of application areas), security and safety (31,4%), monitoring and management (10%), and autonomy (5,7%).

The collaborations targeted situational awareness (34,8%), border management, security and surveillance (10,1%), integrated command, control and coordination platforms (15,9%), Law Enforcement Agency operations (7,2%), maritime surveillance (10,1%), airspace security and safety (7,2%), port of the future and port surveillance (7,2%), electronic warfare (2,9%), land use and urban environment (1,4%), circular economy (1,4%) and the topic “drive to the future” (1,4%).

The ROBORDER project collaborations pertained to several research areas overlapping with ROBORDER interests. The most represented fields were:

- information fusion (28% of project collaboration research areas);
- Internet-of-Things (16%);
- information sharing (10%)
- platform interoperability and artificial intelligence (8%);
- robotics and autonomy, decision support systems, augmented reality and signal processing (6%).

42 project collaborations activities have been reported by ROBORDER partners, which mostly concerned knowledge transfer and exchange (57,1%), joint organisation of events like project workshops, demonstrations and meetings (14,3%), joint participation to events (11,9%), provision of expertise (9,5%), and other networking activities (7,1%).

The details of the standardisations and collaboration activities are presented and analysed in the document. The methodology used for data collection included a structured survey, which was periodically repeated until the end of the project. The document illustrates in detail the qualitative analysis of the collected data, revised in close collaboration of the reference partners.

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List of Acronyms

Acronym	Meaning
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
AUV	Autonomous Underwater Vehicle
CIRAM	Common Integrated Risk Analysis Model
CISE	Common Information Sharing Environment
C2	Command and Control
C3	Command Control and Coordination
DLR	Deutsches Zentrum für Luft und Raumfahrt German Aerospace Center
DSEEP	Distributed Simulation Engineering and Execution Process
DSL	Domain Specification Language
EaaS	Everything as a Service
EDA	European Defence Agency
EDL	Experiment Description Language
EEA	European Economic Area
EGNSS	European Global Navigation Satellite Systems
EMSA	European Maritime Safety Agency
EO	Electro Optical
ESA	European Space Agency
ESIF	European Structural and Investment Funds
EU	European Union
GCS	Ground Control Station
HLA	High Level Architecture
ICMPD	International Centre for Migration and Policy Development
IoT	Internet-of-Things
IR	Infra-Red
ISTAR	Intelligence Surveillance Target Acquisition and Reconnaissance
KPIs	Key Performance Indicators
LSP	Large-Scale Pilot
LEA	Law Enforcement Agencies (LEA)
M2M	Machine-to-Machine
MDCS	Multi Domain Control Station
MDL	Mission Definition Language
Moni.C.A.	Livorno Port Monitoring and Control Application
MQTT	Message Queuing Telemetry Transport
M&S	Modelling and Simulation
NB-IoT	Narrowband Internet-of-Things
NAF	NATO Architectural Framework
NG-IoT	Next Generation Internet-of-Things
PADR	EU Preparatory Action on Defence Research
PBR	Passive Bi-static Radar
POC	Point Of Contact
SAR	Search And Rescue
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aircraft Systems
UCS	UAV Control System
UGV	Unmanned Ground Vehicles
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicles
UX	User eXperience
VV&A	Verification, Validation and Accreditation
XR	EXtended Reality

Table 1 - List of acronyms

1 Introduction

This deliverable reports on the ROBORDER standardisation and project collaboration activities accomplished along the project. Within the scope of the project, these activities supported the collaborative design, development, evaluation and demonstration of the ROBORDER multi-domain border security platform, whose components have been provided by project partners with diverse expertise and responsibilities and that employ a differentiated range of technologies. Standardisation and collaboration activities also ensure the maximum reusability and spreading of project results, enhancing the exploitation of public funding.

The standardisation and project collaboration activities of ROBORDER have been undertaken for the execution of ROBORDER operational tasks in work packages 2-7, then coordinated and reported within Task T7.3.

The development and use of the ROBORDER components comply with nineteen standards, guidelines, best practices, data and architectural models and one standardisation project, which are reported in this document using an analytical approach to illustrate the associated activities and the relation with the ROBORDER topics and tasks. ROBORDER also actively engaged with other twenty-two projects, and the associated collaboration activities are analysed here to illustrate the relation with ROBORDER applications and research topics.

The data in support of this document have been prepared, structured and analysed with the collaboration of the reference ROBORDER partners.

The document is organised as follow. Section 2 describes the data collection and analysis methodology applied to monitor and report the status of the activities. The corresponding data collection templates are included in this document, in Appendix I. The complete overview of standardisation and collaboration activities is illustrated in Section 3 and Section 4, respectively. Section 5 describes relevant activities not included in the previous sections and the update with respect to the previous reporting period. Section 6 concludes the report.

2 Methodology

In the initial phases of the project, preliminary information on standardisation activities and project collaborations was collected by CMRE at executive board meetings, extracting the relevant information from the partner presentations of project tasks. In order to facilitate the coordination and reporting of these activities, this initial information was complemented with the execution of structured focused surveys, periodically revised and updated in collaboration between CMRE and the involved partners. The survey data enabled to analyse the status and overview the progress of the standardisation and project collaboration activities along the project execution.

The applied methodology comprised four steps, as follows.

1) **Data collection:** *a structured collection of information, reviewed interactively with the responsible partners.*
   In June 2020, each ROBORDER partner was requested to participate in a structured survey, to collect detailed information on standardization and external collaboration activities executed in relation to any of the ROBORDER tasks. Each partner was given three tables to fill in, pre-filled with examples, with detailed instructions on how to fill them to describe:
   - The **standards** they used or contributed to;
   - The **standardization committees,** working or technical groups they participated;
   - The **projects** they have collaborated with during the execution of ROBORDER**,** including past, ongoing, or planned projects.

   The survey tables are reported in Appendix I.

The compiled structured surveys were first compared with the information already available and collected during executive board meetings, and shortly followed by focused interviews with each contributing partner to review and discuss the information provided. Afterwards, the partners had the possibility to refine and complement the survey with additional details.

2) **Data preparation:** *a preliminary exploration of results and their reasoned harmonisation to prepare the data for the analysis.*
The received contributions were compared to let relevant activities and dimensions of interest emerge. Data were harmonized, and consistent values for the dimensions of interest for the activities were defined.

3) **Data analysis:** *analysis and summarisation of data with graphical analytics.*
The cleaned and harmonised data were analysed and discussed in this document with the support of graphical analytics. The up-to-date results of the analysis are reported in Section 3 and 4, and constitute the core of this deliverable.

4) **Data update:** *data periodically revision and update.*
The information provided by the partners was revised, and the analysis results updated. After the first structured collection in June 2020, the ROBORDER partners were requested to revise their contributions and amend or integrate any missing information in December 2020-January 2021, and a second time in June 2021.

In Section 5, the progress of the standardisation and collaboration activities after the second project review is reported. The Section also describes relevant activities not included in the previous sections.

3 Standardisation

This Section describes the ROBORDER standardisation activities. Within ROBORDER, nineteen different standards were applied or implemented, which can be classified into seven standard types and according to nine application areas. These standards were in prevalence regulatory frameworks for safe UxV mission operations and information models as data exchange models and ontologies for data interoperability. Architectural models, guideline frameworks and best practices for architecture interoperability and interoperable simulations were also numerous.

The ROBORDER partners also actively contributed to standard development with the definition of an UxV mission specification language and with the participation to the committee for the development of a comprehensive interoperability standard for Machine-to-Machine, i.e., the automated exchange of information between devices without manual intervention by humans, and Internet-of-Things (IoT), i.e., the integration of physical objects in networks to enable to the pervasive application of sensors and software potentially exchanging data on the internet.

The standardisation activities undertaken by ROBORDER partners included standard adoption and alignment, standard enrichment, standard modelling, and the participation to standard committees.

In the rest of the section, ROBORDER standards and standardisation activities are described.

3.1 ROBORDER Standards

The ROBORDER partners used or contributed to nineteen standards and one standardisation project, including:

- Seven information models for exchange and interoperability of information, specifically: maritime and border security data (the Common Information Sharing

Environment – CISE, and the Common Integrated Risk Analysis Model – CIRAM); data transferred to multi-domain control stations and augmented reality devices; geographic map tiles, and temporal information exchanged between the ROBORDER visual analytics and dashboard components, whose communication was harmonised according to a JSON data interchange model;

- One an architectural model for interoperable machine-to-machine IoT technologies, which is under development with the active contribution of ROBORDER through the participation to the associated standardisation project (One Machine-to-Machine - oneM2M - partnership project);
- One architectural model (the High Level Architecture – HLA) and two best practices guiding the development, verification and validation of interoperable simulations;
- Four safety regulatory frameworks, three of them specific for safe UxV mission operation at national and European level;
- One regulation for data protection and privacy at European level (General Data Protection Regulation - GDPR);
- One guideline high-level framework for architecture development, widely applied by industry (NATO Architecture Framework – NAF - 4.0);
- One UxV mission specification language developed within the project;
- One User experience (UX) best practice for the development of highly accessible web interfaces (Web Content Accessibility Guidelines - WCAG).

These standards facilitate the alignment of the ROBORDER platform and components to ongoing European initiatives (as in the case of CISE, CIRAM) and facilitate the uptake by relevant institutions and industry in the area of border security both at European and at wider level (as in the case of oneM2M, NAF and HLA), as illustrated also in the market study presented in deliverable D7.6 Business Model. Other standards enable to ensure the applicability of the proposed solutions, both from safety and usability perspectives (e.g., safety regulations for UxV missions, GDPR, WCAG).

The comprehensive list of standards at large that ROBORDER partners used or contributed to within the project execution is reported in Table 2.

Standard or WG	Standard type	Standard objective	Description	Ref.
Multi Domain Control Station (MDCS) working group UCS 3.4 - STANAG 4586	Information model	Interoperability (data)	*Data exchange model for UAV control system (UCS) interfaces. It defines architectures, interfaces, communication protocols, data elements and message formats, to enable UAV interoperability.*	[1]
Common Information Sharing Environment (CISE) data model	Information model	Interoperability (data)	*Data exchange model and ontologies for maritime information*	[2] [3]
IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)- Framework and Rules IEEE 1516-2010	Architecture model	Interoperability (distributed simulation)	*Interoperability, federation of distributed simulations*	[4]
IEEE Recommended Practice for Verification, Validation, and Accreditation of a	Best practice	Interoperability (distributed simulation)	*Verification and Validation of distributed interoperable simulations*	[5]

Standard or WG	Standard type	Standard objective	Description	Ref.
Federation – and Overlay to the High Level Architecture Federation Development and Execution process IEEE 1516.4 – 2007				
Recommended practice for Distributed Simulation Engineering and Execution Process (DSEEP) IEEE 1730-2010	Best practice	Interoperability (distributed simulation)	*System engineering practices for distributed simulations*	[6]
NATO Architecture Framework Version 4.0 NAFv4	Guideline framework	Architecture development	*Develop and describe architecture artefacts, for both military and business use. It provides a standardized way to develop architecture artefacts, by defining Methodology (how to develop architectures and run an architecture project), Viewpoints (conventions for the construction, interpretation and use of architecture views for communicating the enterprise architecture to different stakeholders), Meta-Model (the application of commercial meta-models identified as compliant with NATO policy), and a Glossary, References and Bibliography.*	[7]
oneM2M ETSI TS 118 - 101 TS-0001 (Functional architecture) V2.10.0 - 113 TS-0013 (Interoperability testing) V2.3.2 - 126 TS-0026 (3GPP Interworking) V3.0.0	Architecture model	Interoperability (M2M IoT)	*Global technical standard for interoperability concerning the architecture, Application Programming Interface (API) specifications, security and enrolment solutions for Machine-to-Machine and Internet-of-Things (IoT) technologies. End-to-end oneM2M functional architecture. The functional architecture focuses on the Service Layer aspects and takes Underlying Network-independent view of the end-to-end services.*	[8] [9] [10]
SmartM2M: One Machine-to-machine partnership project	Standard committee	Interoperability (M2M IoT)		[11]
Commission Delegated Directive (EU) 2015/863 on Restriction of Hazardous Substances RoHS 3	Regulatory framework	Safety	*Restriction on the use of hazardous materials in electrical and electronic products*	[12]
National legislations for operating unmanned aircrafts	Regulatory framework	UxV operations (safety)	*Operation of unmanned aircrafts*	*n.a.*

Standard or WG	Standard type	Standard objective	Description	Ref.
Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft system	Regulatory framework	UxV operations (safety)	*Operation of unmanned aircrafts. Requirements for the design and manufacture of unmanned aircraft systems ('UAS') intended to be operated under the rules and conditions defined in Implementing Regulation (EU) 2019/947 and of remote identification add-ons.*	[13]
Commission implementing Regulation (EU) 2019/947	Regulatory framework	UxV operations (safety)	*Operation of unmanned aircrafts. Detailed provisions for the operation of unmanned aircraft systems as well as for personnel, including remote pilots and organisations involved in those operations.*	[14]
FRONTEX Common Integrated Risk Analysis Model (CIRAM)	Information model	Interoperability (data)	*Facilitate efficient information exchange and cooperation in the field of border security*	[15]
Mission Definition Language	Specification Language	UxV missions	*Domain Specific Language for UxV mission specification*	*n.a.*
Message Queuing Telemetry Transport (MQTT) ISO/IEC 20922:2016	Information model	Interoperability (data)	*Data transfer to Augmented Reality (AR) devices*	[16]
OpenGIS Web Map Tile Service Implementation Standard	Information model	Interoperability (data)	*API for map tiles images using spatially referenced data*	[17]
W3C Web Content Accessibility Guidelines (WCAG) v2.2	Best practice	User Experience (UX)	*Details on making web content more accessible to accessible to people with disabilities*	[18]
Date and Time – Representations for information interchange - ISO 8601:2019	Information model	Interoperability (data)	*International unambiguous calendar-and-clock format*	[19]
Information technology — The JSON data interchange syntax ISO/IEC 21778:2017	Information model	Interoperability (data)	*JavaScript object notation syntax for server/client data interchanges*	[20]
General Data Protection Regulation (GDPR)	Regulatory framework	Data protection and privacy	*Data protection and privacy in the European Union (EU) and the European Economic Area (EEA), protection of natural persons with regard to the processing of personal data and on the free movement of such data*	[21]

Table 2 - ROBORDER Standards and committees. Beside the standard reference, the harmonised categories (type and objective) and a detailed description are reported.

Figure 1 enables to catch the distribution of ROBORDER standards in terms of standard objectives and types.

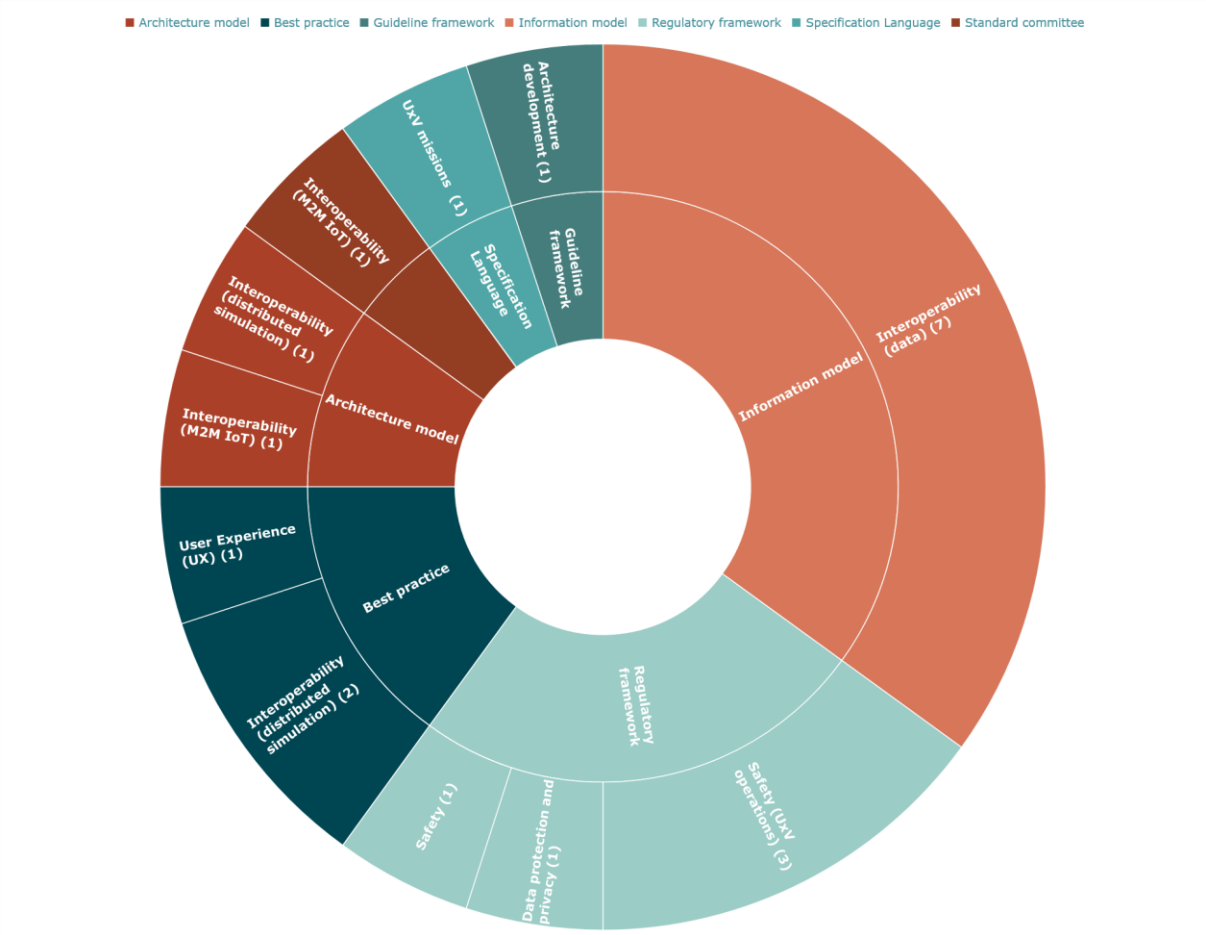

Figure 1 - Application areas and types of the ROBORDER standards.

As illustrated in Figure 1, interoperability standards, for data (brown), distributed simulations (dark green) and Internet-of-Things (sage) are the predominant areas of application, with fourteen (more than 50%) of the ROBORDER standards, and include nine information models, two architecture models, two best practices and the participation to a standardisation project. The remaining standards include a guideline framework for architecture development, regulatory frameworks for safety, in particular for the safety of UxV operations (three standards), one best practice for UX and a specification language for UxV mission.

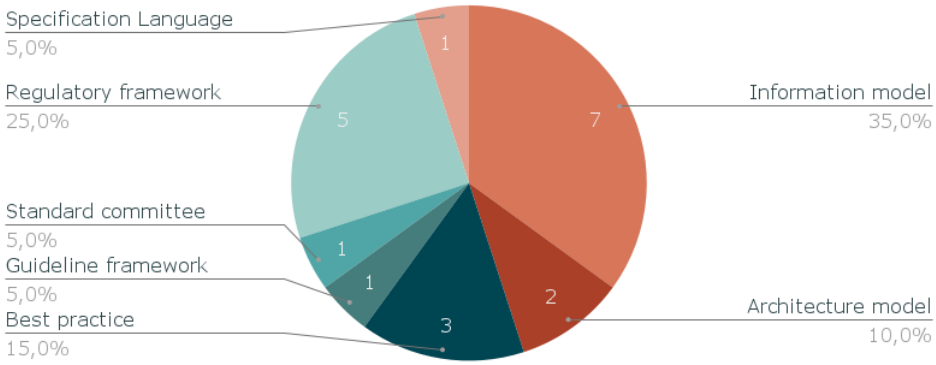

Figure 2 - ROBORDER Standards types. The ROBORDER standard-related activities distribute among regulatory and guideline frameworks, information and architecture models, best practices, specification languages, and one standardisation committee.

The separate distributions of standard types and standard objectives in ROBORDER are illustrated in Figure 2 and Figure 3.

The ROBORDER standards, grouped by standard category, are illustrated in Figure 2, which includes also the standardisation committee ROBORDER partners are participating to. As illustrated above, the majority of ROBORDER standards were information models (for data interoperability) and regulatory frameworks (for safety, in particular the safe execution of UxV operations).

The standard application areas significantly overlap with ROBORDER scientific and technological concepts. As illustrated in Figure 3, interoperability, specifically for data and IoT and distributed simulations, is the prevailing area with twelve standards associated. Four safety standards are included. Three in particular ensure safe UxV operations. Finally, ROBORDER partners aligned to guideline framework for architecture development (NAFv4), development of accessible user interfaces, and to data protection and privacy regulations.

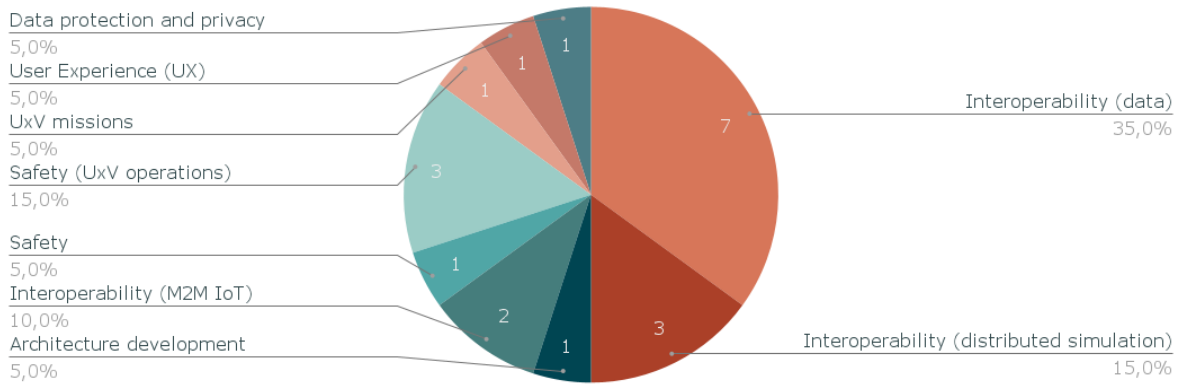

Figure 3 - ROBORDER Standards application areas. The ROBORDER standards application areas overlap with most relevant project topics, in particular UxV operations, UxV missions and interoperability of data and distributed simulations.

3.2 Standardisation activities

Twenty-three standardisation activities were reported during ROBORDER. These are grouped into four types:

- **standard adoption and alignment**, concerning the use of a standard (or guideline, best practice, model) within the execution of a ROBORDER task;
- **standard enrichment and implementation**, where the standard required some adaptation, like an extension, or a custom specification before being applied to execute a task;
- **standard modelling and implementation**, where the standard is specified and developed by ROBORDER partners during project execution;
- **participation to standard committee** (including technical working groups) developing a standard that is used by ROBORDER.

The reported activities grouped by their type are illustrated in the pie chart in Figure 4. The tree map graphs in Figure 5 and Figure 6 show how ROBORDER standard types and standard application areas, as introduced above, distributed among standard activities.

In Figure 4, Figure 5 and Figure 6 activities follow the same colour code to facilitate the analysis.

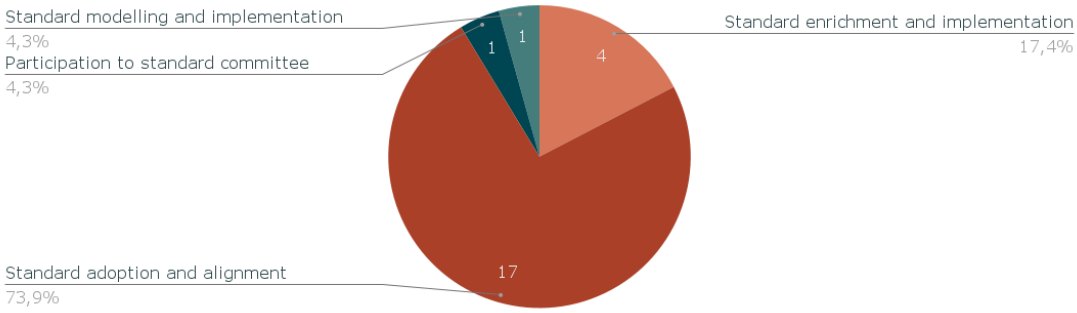

Figure 4 - ROBORDER standardisation activities. See also the associated distribution of standard types and areas.

As shown in the pie-chart in Figure 4, the greatest part of the ROBORDER standardisation effort concerned aligning the project developments to existing standards. As illustrated by Figure 5 and Figure 6, the seventeen reported “standard adoption and alignment” activities (in dark brown in all figures) concerned almost all standard types (with the exception of the type “specification language”), and application areas (with the exception of application area “UxV missions”).

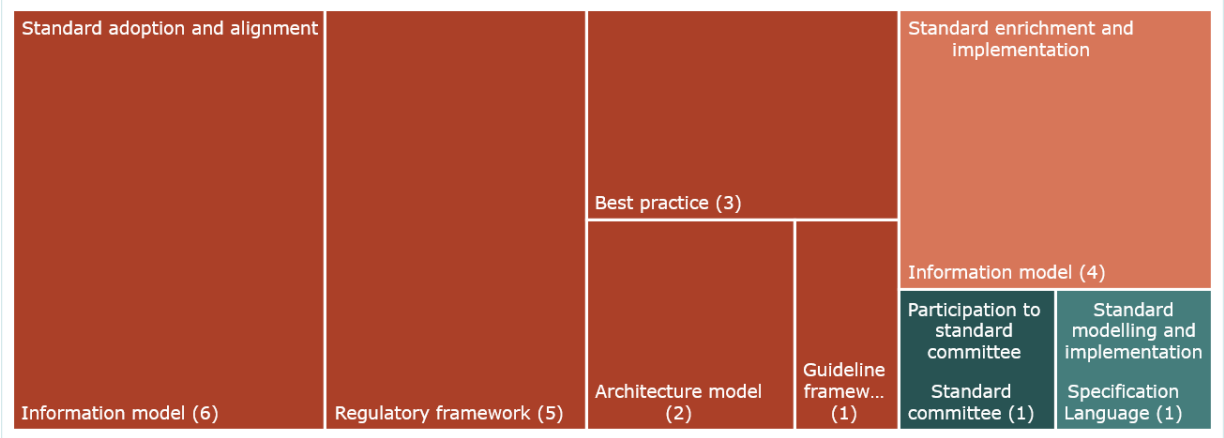

Figure 5 - ROBORDER Standardisation activities and associated standard types. The ROBORDER standards activities relate to: the application of regulatory and guideline frameworks and architecture models; alignment and application of information models and best practices; enrichment of an information exchange model; development and implementation of a specification language; and the participation to a standard committee.

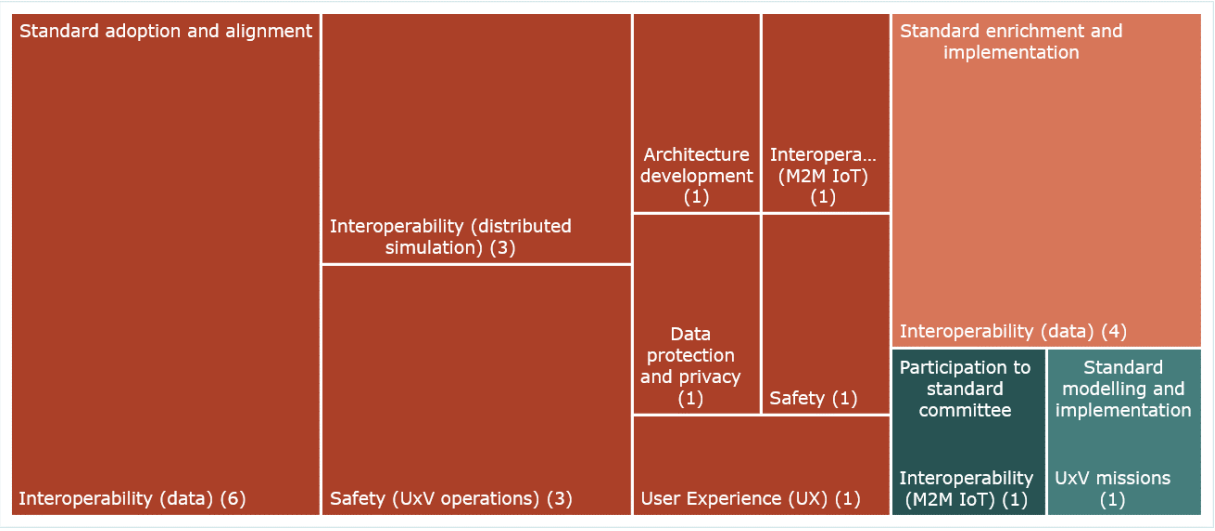

Figure 6 - ROBORDER Standardisation activities and associated standard areas. The ROBORDER standardisation activities address relevant areas of interest for the project, in particular UxV operations and interoperability of data, IoT technologies and simulations.

These activities ensured the interoperability of project components and the operation and evaluation of the resulting integrated platform, as follows:

- Six of the “standard adoption and alignment” activities were associated to the standard with type “Information model” as illustrated in Figure 5 and concerned the adoption of information exchange models, for example for border security risk modelling, for delivering information to augmented reality devices and multi-domain control stations, for the exchange of information between the visual analytic component and the distributed command and control dashboard module and other ROBORDER modules, including the transmission of geographic and time coded information. These six activities correspond to data interoperability standards (“Interoperability (data)” in Figure 6).
- Four critical “standard adoptions and alignment” activities concerned the compliancy to safety regulations for UxV operations and were applied to drone and sensor payload set up. These activities were associated to the type “Regulatory framework” in Figure 5, and corresponds to “Safety” and “Safety (UxV operations)” in Figure 6.
- The remaining “standard adoptions and alignment” to a “Regulatory framework” concerns the application to the European data protection and privacy regulation (“Data protection and privacy” in Figure 6).
- Four “standard adoption and alignment” activities concerned the development interoperable simulations (the High Level Architecture – HLA, the NATO Architecture Framework – NAF) for supporting the evaluation of the ROBORDER platform and to organise the project demonstrations. These correspond to two “Best practice”, one “Architectural model”, and one “Guideline framework” in Figure 5, and to the “Interoperability of distributed simulation” and “Architectural development” clusters of “standard adoptions and alignment” in Figure 6.
- One “standard adoption and alignment” concerned the application of the technical standard oneM2M, a comprehensive technical standard whose aim is to cover multiple aspects of machine-to-machine interoperability and the development of IoT technologies (requirements, architecture, API specifications, security solutions and interoperability), to enable sensor integration and smart object monitoring, which was adopted and implemented in ROBORDER for the interoperation of photonic based radars with the Livorno Port Monitoring and Control Application (Moni.C.A.) (“Architectural model” in Figure 5 and “Interoperability (M2M IoT)” in Figure 6).

- The last "standard adoption and alignment" activity is related to the development of an accessible user interface for the ROBORDER dashboard ("Best practice" in Figure 5 and "User Experience (UX)" in Figure 6).

However, the innovations introduced by the project developments raised the need to adapt existing standard models and introduce new modelling approaches. As shown in Figure 4, Figure 5 and Figure 6, the four "standard enrichment and implementation" activities (light brown in all the figures) are associated to standard of type "Information model" in Figure 5 and "Interoperability (data)" in Figure 6:

- Two of them concerned the semantic formalisation and enrichment of maritime and border security information data exchange models, CISE and CIRAM, respectively. The contribution to the enrichment of CISE was facilitated through the participation in the European Maritime Safety Agency (EMSA) CISE stakeholder group. As a result of this activity, the CISE-OWL ontology has been published, and additional ontologies have been aligned to it to integrate ROBORDER components. The semantic modelling of CIRAM was leveraged to develop a CIRAM-CISE compliant risk management and analysis tool. All these activities were associated.
- The other two concerned the extension of an existing information model for data interoperability of multi-domain control stations (MDCS), in particular for the integration into UGV ground control station (GCS).

The other two groupings in Figure 4, Figure 5 and Figure 6 refer to active contributions to standardisation:

- The activity "standard modelling and implementation" (in gray-green in all figures) concern the development and the implementation of a specification language for UxV missions ("Specification language" in Figure 5 and "UxV mission" in and Figure 6).
- The activity "participation to a standard committee" (in dark green in all figures) is a collaboration undertaken within the "SmartM2M: One Machine-to-Machine partnership project", a global initiative for the development of the oneM2M standard, also used in ROBODER as described above. The active participation of ROBORDER partners to SmartM2M exploited Moni.C.A. as a testbed for the integration of innovative IoT technologies for port monitoring and management. This activity is part of a global initiative paving the way for more interconnected, efficient and secure ports named "Port of the future". An event organised to support this standardisation activity, which is also associated to the project AUTOPILOT, was the TESTFEST 2019[1], which was done in collaboration with the project AUTOPILOT as one of the IoT European Large Scale Pilot (LSP) Projects[2].

The ROBORDER standardisation activities associated to the standards described in this section are categorised and described in details in Table 3.

Standard	Reference partner(s)	Activity	Type of standard activity
Multi Domain Control Station (MDCS) working group UCS 3.4 - STANAG 4586	CERTH	*Extend the standard data model/Partial compatibility with the existing version*	Standard enrichment and implementation
	ROB	*Implement and extend the standard into UGV Ground Control Station*	Standard enrichment and

[1] AUTOPILOT TESTFEST October-November 2019. TESTFEST result workshop, Ertico, Brussels, December 17, 2019: https://erticonetwork.com/interoperability-tests-a-fest-of-encouraging-results/.
[2] IoT European LSP Projects https://european-iot-pilots.eu/

Standard	Reference partner(s)	Activity	Type of standard activity
			implementation
	CMRE	*Alignment with the standard for mission structure for simulated assets*	Standard adoption and alignment
Common Information Sharing Environment (CISE) data model	CERTH	*Implement the CISE ontology and enrich it with the ROBORDER concepts*	Standard enrichment and implementation
IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)- Framework and Rules IEEE 1516-2010	CMRE	*Design, implementation and V&V of a federation of interoperable distributed Modelling and Simulation capability to support the evaluation of the ROBORDER platform and the organization of the demonstration.*	Standard adoption and alignment
IEEE Recommended Practice for Verification, Validation, and Accreditation of a Federation - an Overlay to the High Level Architecture Federation Development and Execution Process IEEE 1516.4-2007 -	CMRE		Standard adoption and alignment
Recommended practice for Distributed Simulation Engineering and Execution Process (DSEEP) IEEE 1730-2010	CMRE		Standard adoption and alignment
NATO Architecture Framework Version 4.0 NAFv4	CMRE		Standard adoption and alignment
oneM2M ETSI TS 118 101 V2.10.0 113 V2.3.2 126 V3.0.0	CNIT AdSP-MTS	*Enable interoperation between Photonic based Radars and Livorno Port Monitoring and Control Application (Moni.C.A.)*	Standard adoption and alignment
SmartM2M: One Machine-to-machine partnership project	CNIT AdSP-MTS		Participation to standard committee
RoHS 3 Directive 2015/863 Restriction of Hazardous Substances	COPT	*Setting up drone and payload*	Standard adoption and alignment
National legislations for operating unmanned aircrafts	COPT		Standard adoption and alignment
Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft system	COPT		Standard adoption and alignment

Standard	Reference partner(s)	Activity	Type of standard activity
Commission implementing Regulation (EU) 2019/947	COPT		Standard adoption and alignment
FRONTEX Common Integrated Risk Analysis Model (CIRAM)	UoA	*Alignment to the conceptual framework. Implementation of a risk management tool that complies with CIRAM and analyses risks*	Standard adoption and alignment
	UoA	*Semantic (ontology-based) mapping of the FRONTEX Common Integrated Risk Analysis Model, CIRAM, risk analysis output to the Common Information Sharing Environment, CISE ontology items.*	Standard enrichment and implementation
Mission Definition Language	UoA	*Adoption of ECLIPSE XTEXT. Specialization in the direction of UxV management. Implementation of compatible tools.*	Standard modelling and implementation
Message Queuing Telemetry Transport (MQTT) ISO/IEC 20922	VTT	*Enables data transfer to mobile and extended reality (XR) devices as they are not supporting KAFKA messages*	Standard adoption and alignment
OpenGIS Web Map Tile Service Implementation Standard (OGC WMTS)	CENTRIC	*Sharing map tile data among ROBORDER modules, including the visual analytics module and command and control module, especially for custom maps and offline use.*	Standard adoption and alignment
Web Content Accessibility Guidelines (WCAG)	CENTRIC	*Making the interface of the web-based dashboard accessible to users with disabilities or impairments.*	Standard adoption and alignment
Date and time — Representations for information interchange ISO 8601	CENTRIC	*ISO 8601 data and time format is adopted to enforce local in the dashboard and in the visual analytics module, to avoid time zone mismatches in the distributed ROBORDER platform*	Standard adoption and alignment
Information technology — The JSON data interchange syntax ISO/IEC 21778:2017	CENTRIC	*JSON data interchange syntax is used throughout the visual analytics module to send and receive data between the visual analytics server and the dashboard interface. The access module of the dashboard is standardised, enabling the future integration with novel data models.*	Standard adoption and alignment
General Data Protection Regulation (GDPR)	CERTH (on behalf of consortium)	*Assist the consortium in complying with ongoing European legislation on personal data protection and assess compliance is met*	Standard adoption and alignment

Table 3 - ROBORDER standards and associated standardisation activities

Figure 7 and Figure 8 illustrate how standardisation activities distributed among project work packages and tasks, respectively. As shown in Figure 7, WP4 was the most represented work package with ten activities associated, followed by WP6 (five activities), WP3 and WP2 (four activities) and WP5 (three activities).

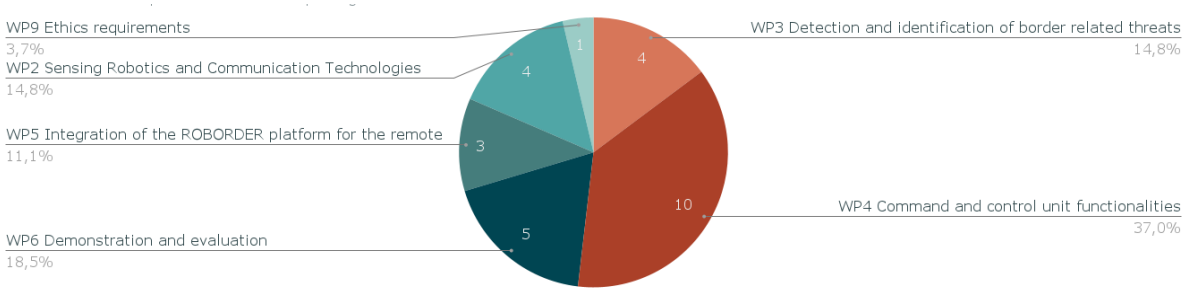

Figure 7 - ROBORDER Standardisation activities per work package.

Regarding ROBORDER tasks, as we can see in the bar chart in Figure 8, Task 4.6 Visual analytics and decision support and Task 6.3 Preparation and implementation of test-plans as simulated exercises were associated to five standardisation activities, while Task 2.5 Reconfiguration of agents and carrier solutions and Task 3.2 Identification and tracking of illegal activities to four activities each, Task 4.5 Risk models to three, Task 5.4 ROBORDER system integration and Task 4.4 CISE compliant common representation model and semantic reasoning to two activities, and the remaining tasks to one activity each.

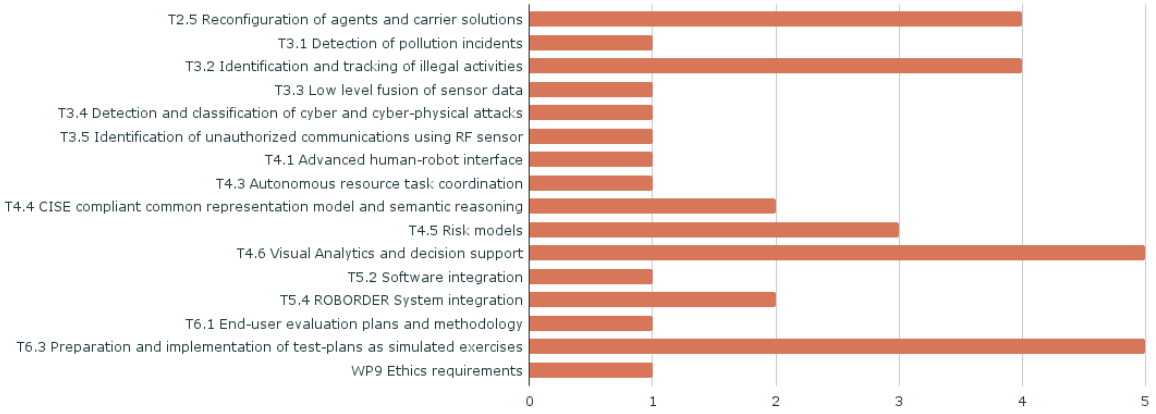

Figure 8 - ROBORDER Standardisation activities per task.

4 Project collaborations

This section describes the ROBORDER project collaboration activities. Along its duration, ROBORDER had active collaborations with twenty projects, including:

- fifteen Horizon 2020 projects;
- two European Defence Agency projects (EDA) including one CapTech RF Sensors Technologies (RADAR) project and one Preparatory Action for Defence Research (PADR) project;
- one EU structural and Investment funds project;
- one Federal research project funded by DLR (Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center), and
- one European Space Agency (ESA) project.

Figure 9 presents the distribution of the ROBORDER collaboration funding agencies.

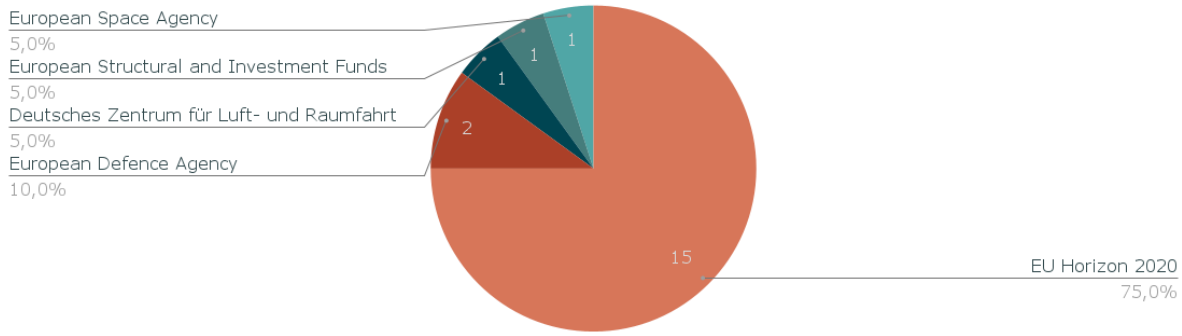

Figure 9 - ROBORDER project collaborations: funding agencies.

The collaborations comprised from one to six ROBORDER partners each. The collaboration with the Horizon 2020 project ARESIBO (Augmented Reality Enriched Situation awareness for Border security), which started in 2019, dealt with six ROBORDER partners, whilst the majority of project collaborations involved two (three collaborations) or one (eight collaborations) of the ROBORDER partners.

Figure 10 illustrates the execution times of the projects ROBORDER collaborated with, comparing them with the duration of ROBORDER (in orange, on top of the graph), while Figure 11 shows the status of these projects at the date of the preparation of these deliverable, in August 2021. ROBORDER had active partnerships since its beginning (with projects RANGER, RAWFIE, AUTOPILOT, CAMELOT, EISIF AI), and could leverage on relevant expertise on sensors, autonomy, drones and surveillance. The number of partnerships increased along the project execution and at the end of the project, in August 2021, ROBORDER partners had still eleven active project collaborations in place (ARESIBO, CONNEXIONs, OCEAN 2020, CapTech JAMPAR, LuFo VI, CREST, ILEANET, iNGENIOUS, SENSORS@SEA, iPROCURENet), hence facilitating the transfer of project knowledge and supporting the exploitation of project results.

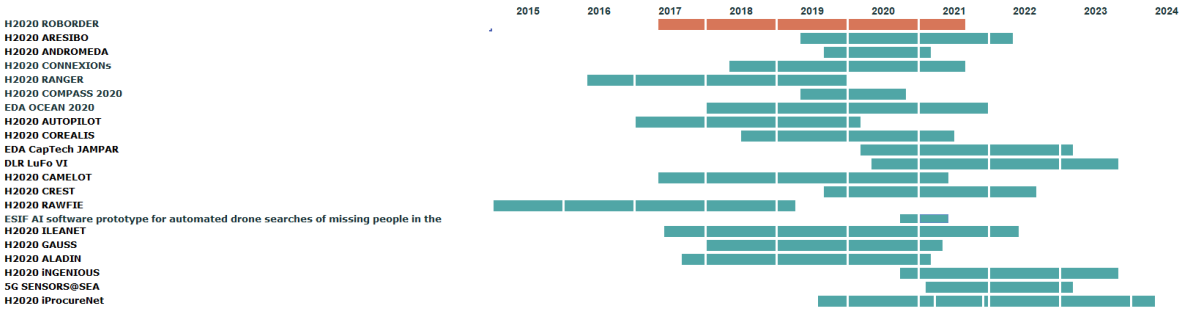

Figure 10 - Overview ROBORDER project collaborations with time ranges. For comparison, the ROBORDER duration is highlighted in orange.

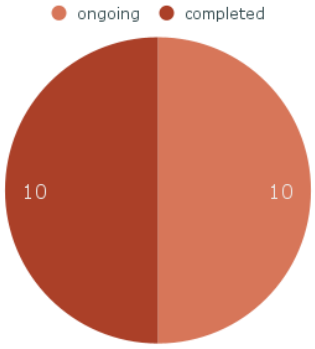

Figure 11 - Status of ROBORDER project collaborations (August 2021).

Figure 12 illustrates the spatial distribution of the project consortiums of these collaborations. Organisations from thirty-three countries were involved in ROBORDER collaborations, mostly European and including two extra-European countries, i.e., Israel and South-Korea, participating to four (ANDROMEDA, CONNEXIONs, CREST, iLEAnet) and one project (AUTOPILOT), respectively. The most recurring countries are Italy and Spain (twelve collaborations each); France, Greece, and Germany (eleven collaborations); Portugal and United Kingdom (nine collaborations). The detail of European countries participation is shown in Figure 13.

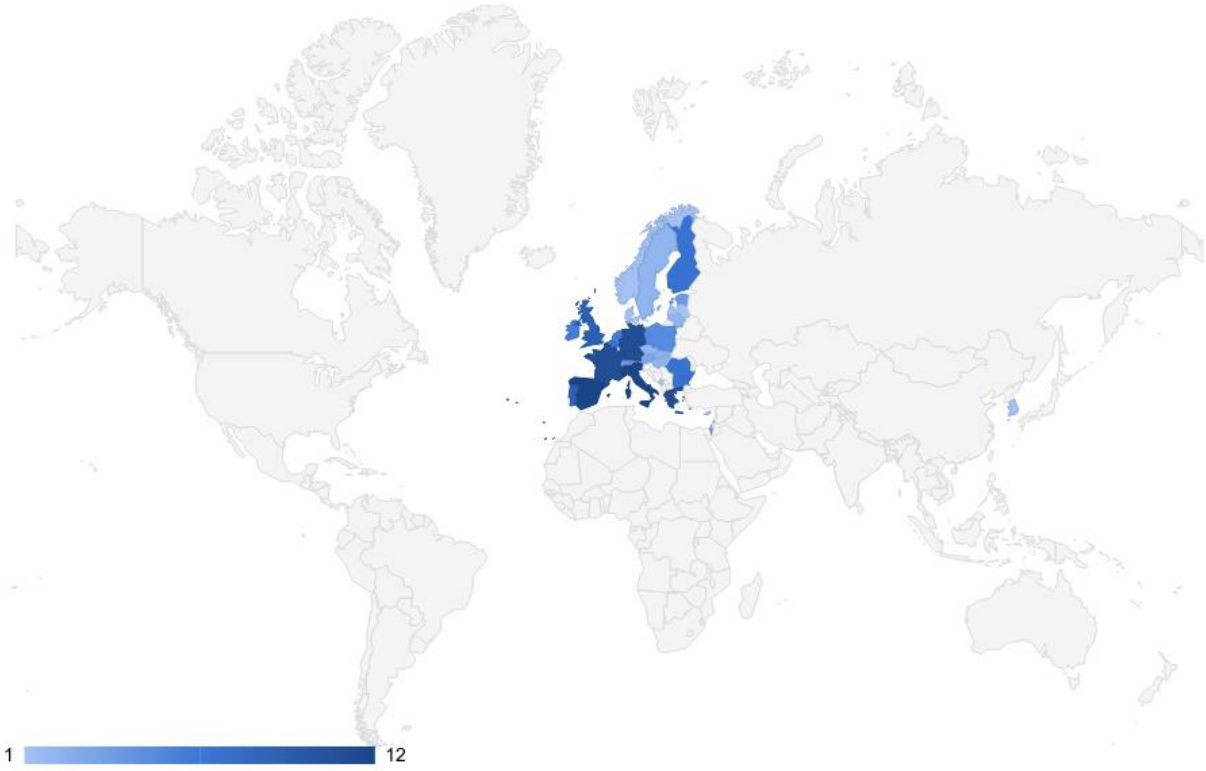

Figure 12 - Global distribution of the project consortiums of ROBORDER project collaborations. Project consortiums are mostly European, with the addition of two extra-European countries, South Korea and Israel. South Korea participate in AUTOPILOT, while Israeli partners participate to four projects: ANDROMEDA, CONNEXIONs, CREST, iLEAnet.

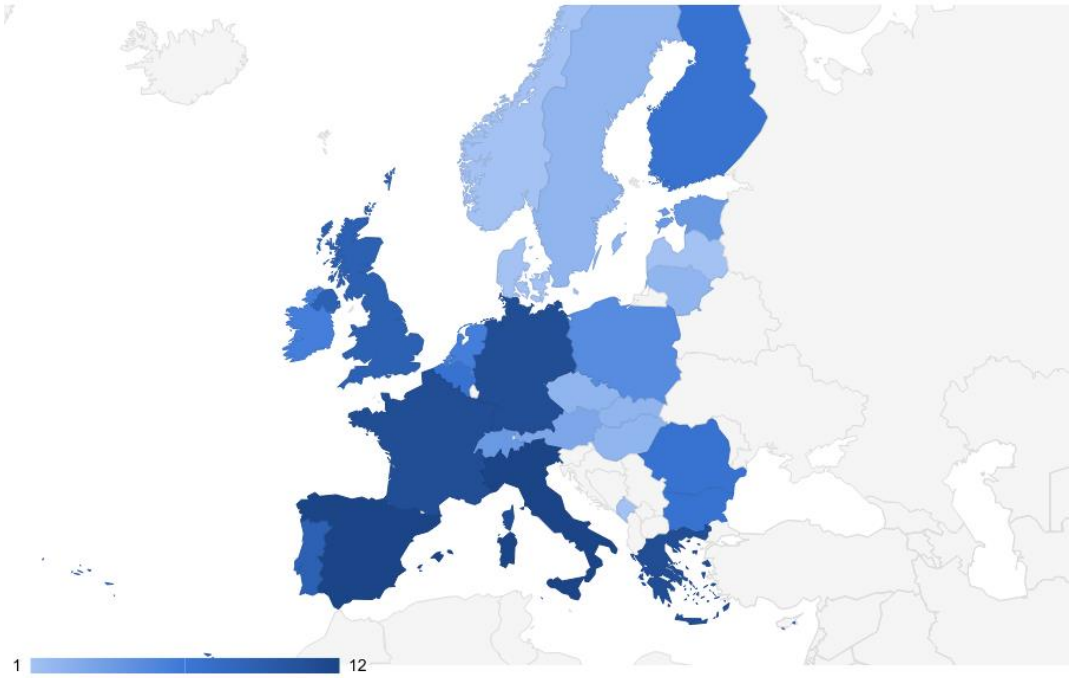

Figure 13 - Distribution of the European partners in ROBORDER project collaborations. Most represented countries are Italy, Spain, France, Greece, and Germany.

The complete list of the projects ROBORDER collaborated with is presented in Table 4. The table reports the funding agencies and the framework programme of each project, the period of execution, and the reference the project website, if available.

Project Name	Funding agency with framework programme	Project title	Period	Ref.
ARESIBO	EU Horizon 2020	Augmented Reality Enriched Situation awareness for Border security	May 2019 – Apr 2022	[22]
ANDROMEDA	EU Horizon 2020	An Enhanced Common Information Sharing Environment for Border Command, Control and Coordination Systems	Sep 2019 – Feb 2021	[23]
AUTOPILOT	EU Horizon 2020	Automated driving Progressed by Internet-of-Things	Jan 2017 - Feb 2020	[24]
CAMELOT	EU Horizon 2020	C2 Advanced Multi-domain Environment and Live Observation Technologies	May 2017 – May 2021	[25]
JAMPAR	European Defence Agency / CapTech RF Sensors Technologies	CapTech RF Sensors Technologies (RADAR) JAMPAR	Feb 2020 – Feb 2023	[26]
COMPASS 2020	EU Horizon 2020	Coordination of Maritime Assets for Persistent and Systematic Surveillance	May 2019 - Oct 2020	[27]
CONNEXIONs	EU Horizon 2020	InterCONnected NEXt-Generation Immersive IoT Platform of Crime and	Sep 2018- Aug 2021	[28]

Project Name	Funding agency with framework programme	Project title	Period	Ref.
		Terrorism DetectiON, PredictiON, InvestigatiON, and PreventiON Services		
COREALIS	EU Horizon 2020	The Port of the Future	Jun 2018 – Jun 2021	[29]
CREST	EU Horizon 2020	Fighting Crime and TerroRism with an IoT-enabled Autonomous Platform based on an Ecosystem of Advanced IntelligEnce, Operations, and InveStigation Technologies	Sep 2019-Aug 2022	[30]
OCEAN 2020	European Defence Agency / EU Preparatory Action on Defence Research (PADR)	Open Cooperation for European mAritime awareNess	2018-2021	[31]
RANGER	EU Horizon 2020	RAdars for loNG distance maritime surveillancE and SaR opeRations	May 2016 – Dec 2019	[32]
RAWFIE	EU Horizon 2020	Road Air and Water Based Future Internet Experimentation	Jan 2015 – Mar 2019	[33]
LuFo VI	Federal research programme aeronautics	LuFo VI	Apr 2020 – Oct 2023	[34]
AI software prototype for automated drone searches of missing people in the landscape	European Structural and Investment Funds/ Ministry of Economic Affairs and Communications	AI software prototype for automated drone searches of missing people in the landscape	Oct 2020 – May 2021	n.a.
iLEAnet	EU Horizon 2020	Innovation by Law Enforcement Agencies networking	Jun 2017 - May 2022	[35]
GAUSS	EU Horizon 2020	Galileo Egnos as an Asset for UTM Safety and Security	Jan 2018-Apr 2021	[36]
ALADDIN	EU Horizon 2020	Advanced hoListic Adverse Drone Detection, Identification and Neutralization	Sep 2017 – Feb 2021	[37]
iNGENIOUS	EU Horizon 2020	Automated driving Progressed by Internet-of-Things	Oct 2020 - Oct 2023	[38]
SENSORS@SEA	European Space Agency	5G Smart Edge Node and Smart Objects enabling Reliable Services Extended all over the seas	Feb 2021 - Feb 2023	n.a.
iPROCUREnet	EU Horizon 2020		May 2019 – Apr 2024	[39]

Table 4 - ROBORDER Projects collaborations.

In the rest of the section, the analysis of the topics of ROBORDER project collaborations is presented.

4.1 Topics of ROBORDER project collaborations

The ROBORDER project collaborations supported the investigations and developments of ROBORDER on key domains and topics of interest for the project, boosting innovation and facilitating the dissemination and exploitation of the project results via transfer of knowledge.

Figure 14 presents the application domains addressed by ROBORDER collaborations. As shown by the graph, all domains of interest for border surveillance, i.e., sea, land, air, and underwater are represented, with a prevalence of sea (fourteen projects) and land (eleven projects).

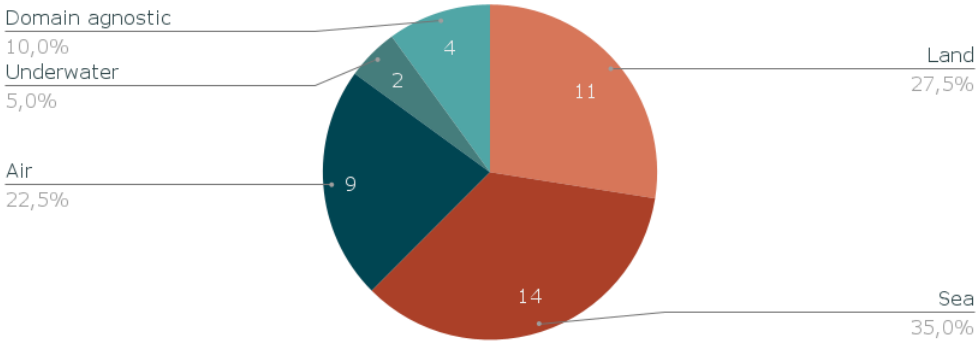

Figure 14 - ROBORDER Project collaboration domains. Fifteen of the projects that collaborated with ROBORDER addressed sea use cases, twelve land, ten air, two the underwater domain and other four projects where not addressing explicitly any of the four domains.

The radar graph in Figure 15 clarifies that, like ROBORDER, most of the projects adopted a synergic multi-domain approach: six projects addressed sea, land and air; one all four domains; one sea, air ad underwater; three land and sea; four projects ROBORDER collaborated with (CapTech JAMPAR, CONNEXION, CREST, and iPROCUREnet) supported diversified security aspects, with no reference to any particular domain. Two of them, CREST and CONNECTION, specifically developed domain agnostic IoT technologies for crime and terrorism prevention in support of Law Enforcement Agencies (LEA). The remaining projects addressed only one domain among land, sea, and air, with a prevalence of sea (three projects).

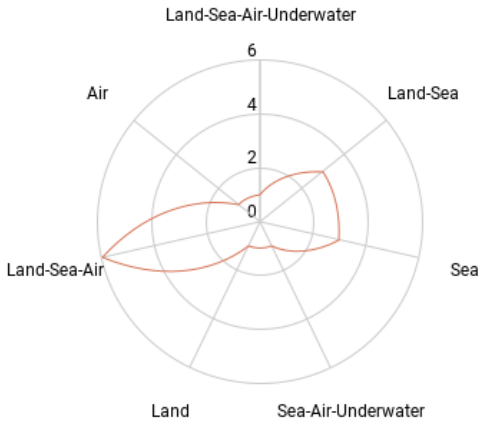

Figure 15 - Multi-domain and single-domain projects among ROBORDER project collaborations. The projects ROBORDER collaborated with were active in all land, sea, air and underwater domains. One project addressed all four domains; six projects addressed land, sea and air, while one tackled sea, air and underwater; three projects addressed land and sea. All

other projects addressed only one domain: three projects addressed the sea, one land and one air.

For an in deep comparison of the project collaborations and to illustrate how they relate with ROBORDER, project collaboration topics were manually extracted from project websites and complemented or refined by the ROBORDER partners involved in the collaborations. The resulting list of topics was harmonised into ad-hoc categories, then used to define taxonomies for application areas, objectives and use cases, research areas and techniques, platforms and the sensors, useful to cluster the project collaborations and ease the comparison with ROBORDER topics.

The results of this analysis and the comparison with ROBORDER activities are illustrated in this section with the support of the diagrams in Figure 19 – Figure 21. The original list of topics of ROBORDER project collaborations is reported in Table 5.

Project	Topics
H2020 ARESIBO	Border management, security and surveillance
	Situational awareness
	Unmanned Systems and Vehicles
	mobile Augmented Reality
	Extended reality
	Wearables telecommunications
	Swarm robotics
	Context-aware Autonomous missions planning
	Artificial intelligence
	Cloud-based Decision-support services and tools
	Command and Control
	Multi-domain Mission Systems
	Data fusion
	Threat risk analysis
	Unmanned Ground Vehicles
	Unmanned Aerial Vehicles
	Unmanned Underwater Vehicles
	Unmanned Surface Vehicles
H2020 ANDROMEDA	Data exchange model
	Maritime CISE Model
	Border management, security and surveillance
	Data Fusion
	Command Control and Coordination
	Surveillance Information Exchange
	Law Enforcement Agencies operations
	Maritime traffic control
	Illegal activities smuggling
	Illegal immigration and human trafficking detection
	Search And Rescue
	Decision support services
	Data analytics
H2020 CONNEXIONs	Crime prediction and prevention
	Heterogeneous multimodal data
	Augmented and virtual reality
	Law Enforcement Agencies operations
	crime investigation and training
	crime-scene simulation
	3D scene reconstruction
	Illegal immigration and human trafficking detection
	Terroristic attack
	Multimodal information extraction and integration

Project	Topics
	threat assessment
	Situational awareness
	Internet-of-Things
H2020 RANGER	Radar
	early warning
	Surveillance platform
	maritime Surveillance
	Machine/deep learning
	Vessel tracking, detection, recognition, and identification
	Maritime CISE Model
H2020 COMPASS 2020	Maritime Surveillance operations
	Unmanned Systems and Vehicles
	Long range and persistent surveillance
	Multi-domain Mission Systems
	Data fusion
	Threat risk analysis
	Interoperability
EDA OCEAN 2020	Maritime Situational Awareness
	Unmanned Systems and Vehicles
	Recognized Maritime Picture
	Intelligence Surveillance Target Acquisition and Reconnaissance
	Multi-domain unmanned vehicles
H2020 AUTOPILOT	Large-Scale Pilots
	autonomous vehicle in a connected environment
	Internet-of-Things
	autonomous driving vehicles
	open data
H2020 COREALIS	Port technologies
	Port of the future
	Port capacity and traffic prediction
	Internet-of-Things
	Data analytics
	Next generation traffic management and emerging 5G networks
	Cargo ports
	Land use and urban environment
	Situational Awareness
	Container Terminal Operational Efficiency
	Circular economy
EDA CapTech JAMPAR	Passive Radar
	Electronic Warfare
	Jammer signals
	Signal processing
	Non-cooperative target classification and identification
DLR LuFo VI	passive bi-static radar systems
	airspace Security
	small air targets
	Unmanned Aerial Vehicles
H2020 CAMELOT	Border management, security and surveillance
	Multi-domain Mission Systems
	Data fusion
	sensors (Electro-optical, radar, Infrared)
	Unmanned Systems and Vehicles
	Integrated situational picture
	modular and scalable Command and Control
	standardisation

Project	Topics
	integrated operational platform
H2020 CREST	Surveillance
	Law Enforcement Agencies operations
	Crime and terrorism prediction and prevention
	Threat risk analysis
	Situational awareness
	Investigation
	Prediction, prevention, operation, and investigation platform
	Multidimensional heterogeneous data stream integration and correlation
	Multi-domain Mission Systems
	Interactive augmented reality environments
	Monitoring, tracking, and analytics
	Distributed operational Command and Control
	Confidence and trustworthiness of information sharing
	Block chain technologies
	Automatic early warning
	Automated detection, identification, assessment, fusion, and correlation of digital evidence
	Visual analytics
	Data fusion
	Internet-of-Things
	Unmanned Systems and Vehicles
	Surface/Deep/Dark Web
	Social media
	Wearable sensors
	Surveillance cameras
H2020 RAWFIE	Internet-of-Things
	Integrated platform
	Unmanned Systems and Vehicles
	Vehicular aerial and maritime environments
	Cloud
	Everything as a Service
	Unmanned Ground Vehicles
	Unmanned Aerial Vehicles
	Unmanned Surface Vehicles
ESIF AI software prototype for automated drone searches of missing people in the landscape	Rescue operations
	Unmanned Systems and Vehicles
	online data fusion
	Artificial Intelligence
H2020 iLEAnet	Law Enforcement Agencies
	Border management
	Registration of irregular migrants
	Pre-frontier area monitoring
	Innovative technologies for border management
H2020 GAUSS	Unmanned Aircraft Systems
	Geofencing
	Remotely Piloted Aircraft System
	Command and Control
	Data fusion
	Situation awareness
	Unmanned Aerial System traffic management
	European Global Navigation Satellite Systems
	Security of Communications
	Safety of operations
	Very Low Level operations

Project	Topics
	Remotely Piloted Aircraft System operations
	Anti-jamming and anti-spoofing capabilities
H2020 ALADDIN	Counter Unmanned Aerial Vehicles
	Unmanned Aerial Vehicles threat
H2020 iNGENIOUS	Machine-to-Machine Orchestrator/Interoperability
	Next generation Internet-of-Things
	Management of different communication layers
	Port technologies
	Port of the future
	Port capacity and traffic prediction
	Next generation traffic management and emerging 5G networks
	Cargo ports
	Data management
	Artificial Intelligence
	Enhanced supply chain
5G SENSORS@SEA	Port technologies
	Port of the future
	Internet-of-Things
	Monitoring platform
	Real time container monitoring/tracking
iPROCUREnet	Security Procurement practices
	Security Procurement networking
	Security Procurement community
	Security investment strategies

Table 5 - Project topics of ROBORDER project collaborations. Topics were extracted manually from project websites, refined and complemented with the help of the ROBORDER partners involved in each collaboration.

4.1.1 Project collaboration application areas, objectives, use cases

ROBORDER project collaborations were clustered into five project collaboration areas which are of interest for ROBORDER: surveillance, security, safety and security, monitoring and management, autonomy, as follows:

- **Surveillance**, which refers to monitoring (of people, areas, information, activities, systems) and whose purpose is the collection of surveillance information;
- **Security**, whose objective is the protection of people and assets from deliberate threats, which are intentionally caused (e.g., by pursuing some criminal activities);
- **Safety**, which aims to protect people and assets from unintentional hazards (e.g., casualties and incidents);
- **Monitoring** and management, which implies surveillance, but whose purpose is the management of a facility, a group of people or an asset;
- **Autonomy** refers to a broad range of applications focused on innovative solutions for unmanned vehicles and systems.

The harmonised application areas, objectives and use cases of the projects ROBORDER collaborated with are illustrated in Figure 16, 17, 18, and in the sunburst chart in Figure 19.

Figure 19 and Figure 16 are colour coded to ease comparison. Surveillance areas, objectives and use cases in Figure 19 are light brown, security ones brown, safety and security grey-green, monitoring and management light green, autonomy dark green.

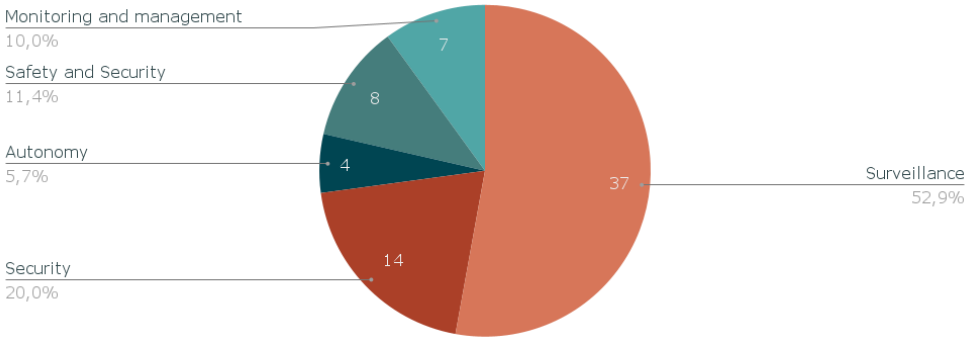

Figure 16 - Areas of applications of ROBORDER project collaborations.

As illustrated in Figure 16, the application areas of ROBORDER project collaborations felt mainly in the area of surveillance (52,9% of application areas), security and safety, including security only (31,4%), with interest for monitoring and management (10%) and autonomy (5,7%).

Figure 17 illustrates the primary project objectives of ROBORDER project collaborations. These projects mostly targeted situational awareness (34,8%, including maritime situational awareness), border management, security and surveillance (10,1%), the development of integrated platforms e.g. C2 or C3 systems (15,9%), LEAs operations (7,2%), maritime surveillance (10,1%), airspace security and safety (7,2%), port of the future and port surveillance (7,2%), electronic warfare (2,9%), land use and urban environment, circular economy and drive to the future (1,4% each).

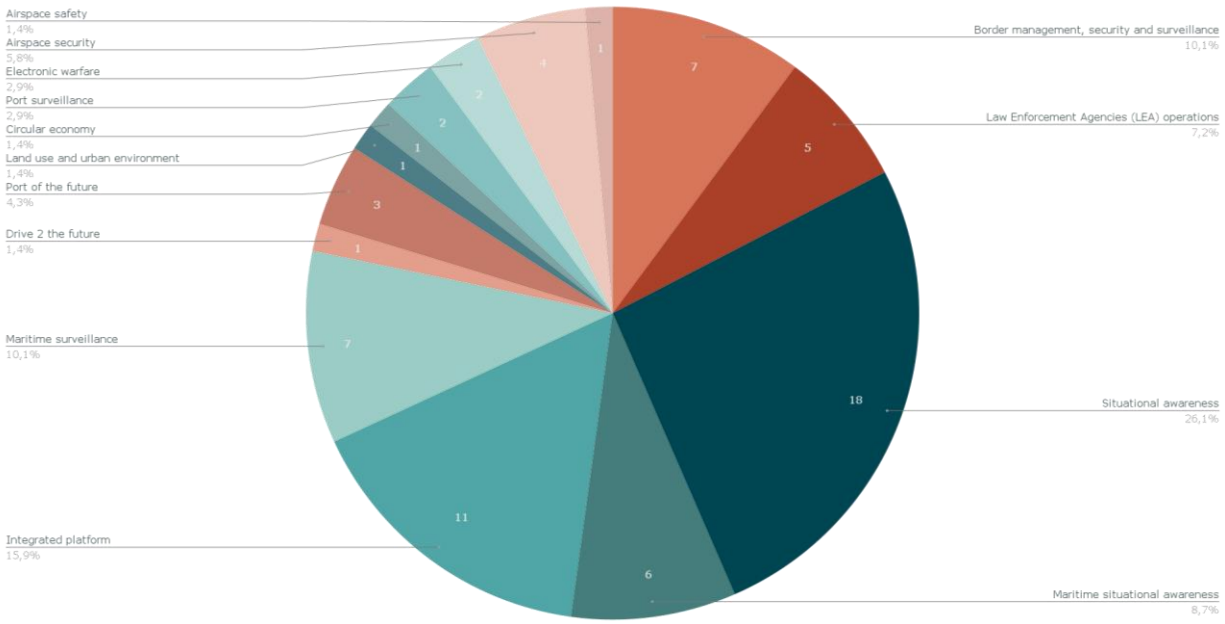

Figure 17 - Primary project objectives of ROBORDER project collaborations.

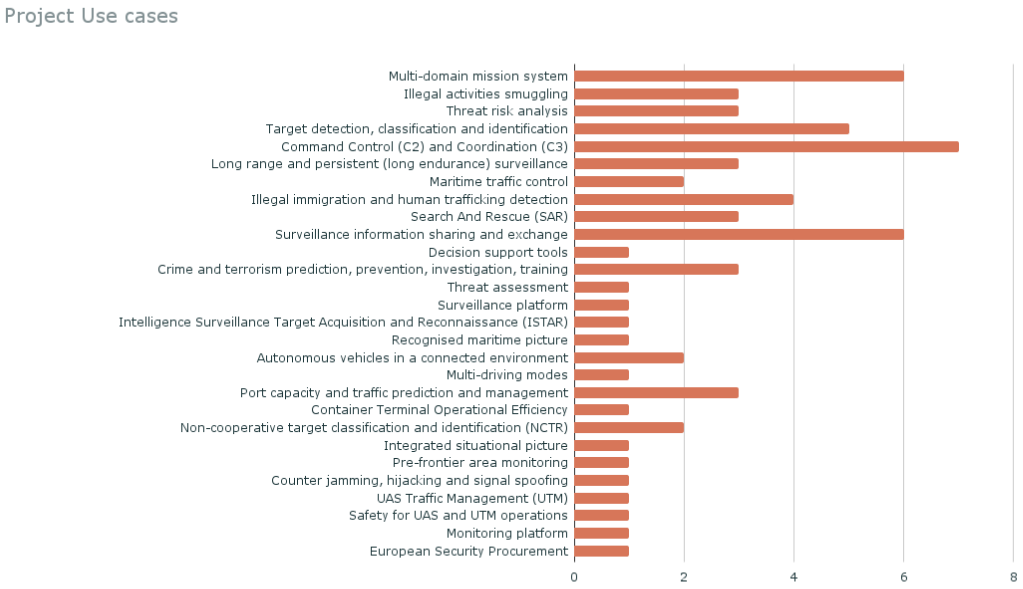

Figure 18 - Use cases of ROBORDER project collaborations.

Among project use cases, Command Control (C2) and Coordination (C3) is the most recurring one (seven collaborations), followed by: multi-domain mission systems and surveillance information sharing and exchange (six collaborations each); target detection, classification and identification (five collaborations); long-range and persistent (long-endurance) surveillance, threat risk analysis, and illegal immigration and human trafficking detection (four collaborations each); illegal activities smuggling, Search and Rescue (SAR), crime and terrorism prediction, prevention, investigation, training, and port capacity and traffic prediction and management (three collaborations each); maritime traffic control, surveillance platform, autonomous vehicles in a connected environment, and non-cooperative target classifiication and identification (two collaborations each). See also Figure 18 for the complete list of use cases.

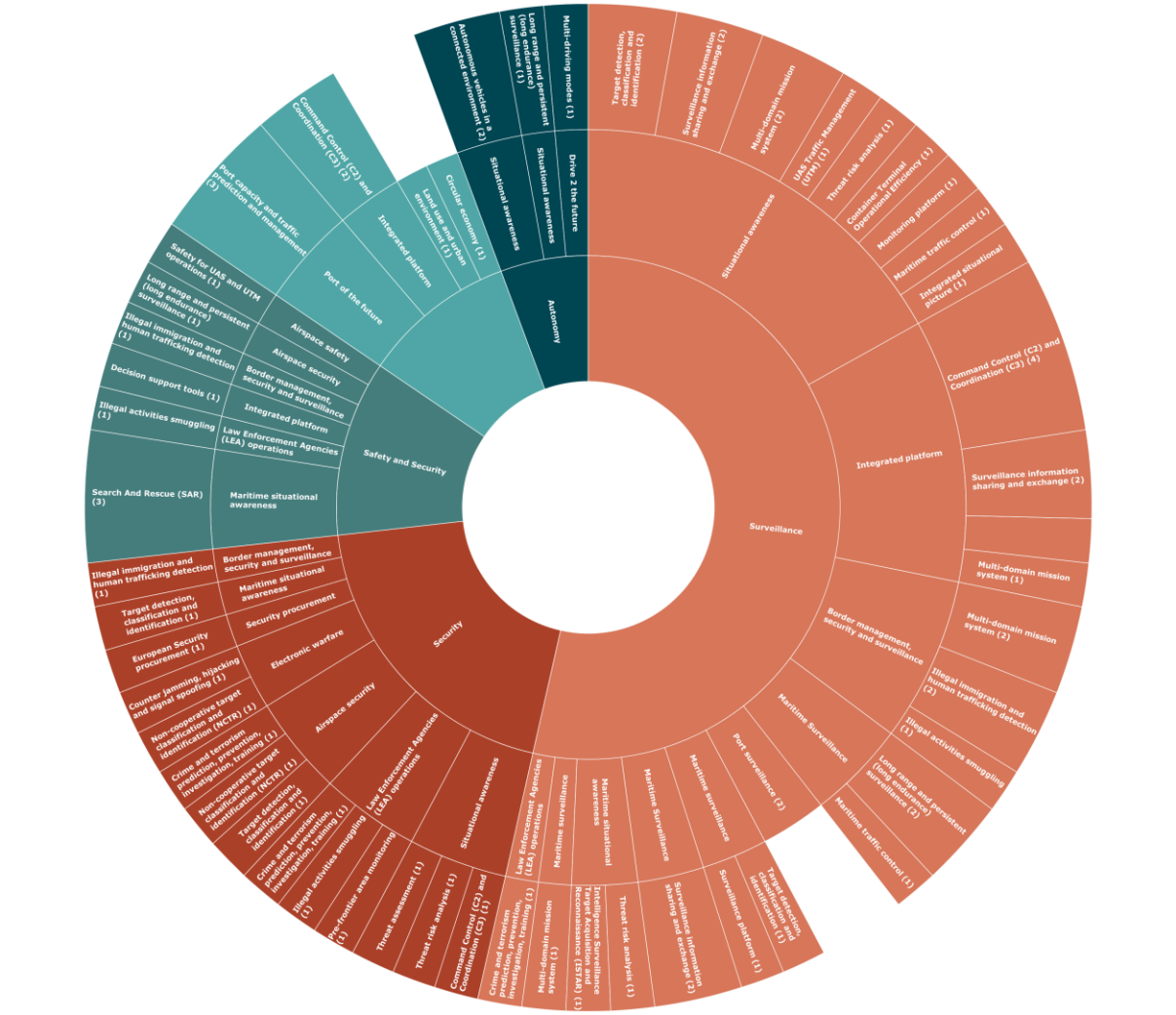

Figure 19 - Hierarchical representation of ROBORDER project collaboration areas, objectives and use cases

The complete picture of project collaboration application areas, objectives and use cases is given in Table 6, which includes also project domains.

Project	Domains	Application areas	Objectives	Use cases
H2020 ARESIBO	Land, Sea, Air, Underwater	Surveillance	Border management, security and surveillance	Multi-domain mission system
		Security	Law Enforcement Agencies (LEA) operations	Illegal activities smuggling
		Security	Situational awareness	Threat risk analysis
		Security	Maritime situational awareness	Target detection, classification and identification
		Surveillance	Integrated platform	Command Control (C2) and Coordination (C3)
		Autonomy	Situational awareness	Long range and persistent (long endurance) surveillance
H2020 ANDROMEDA	Land, Sea	Surveillance	Maritime surveillance	Maritime traffic control
		Safety and Security	Law Enforcement Agencies (LEA) operations	Illegal activities smuggling
		Safety and Security	Border management, security and surveillance	Illegal immigration and human trafficking detection
		Safety and Security	Maritime situational awareness	Search And Rescue (SAR)
		Surveillance	Maritime surveillance	Surveillance information sharing and exchange
		Surveillance	Integrated platform	Command Control (C2) and Coordination (C3)
		Surveillance	Integrated platform	Surveillance information sharing and exchange
		Safety and Security	Integrated platform	Decision support tools
H2020 CONNEXIONs		Security	Law Enforcement Agencies (LEA) operations	Crime and terrorism prediction, prevention, investigation, training
		Surveillance	Border management, security and surveillance	Illegal immigration and human trafficking detection
		Security	Situational awareness	Threat assessment
H2020 RANGER	Sea	Surveillance	Maritime surveillance	Surveillance platform
		Surveillance	Maritime surveillance	Target detection, classification and identification
		Surveillance	Integrated platform	Surveillance information sharing and exchange
H2020 COMPASS 2020	Sea	Surveillance	Maritime surveillance	Long range and persistent (long endurance) surveillance
		Surveillance	Maritime situational awareness	Threat risk analysis
		Surveillance	Maritime surveillance	Multi-domain mission system
		Surveillance	Maritime surveillance	Surveillance information sharing and exchange
		Surveillance	Border management, security and surveillance	Illegal activities smuggling
		Surveillance	Border management, security and	Illegal immigration and human trafficking detection

Project	Domains	Application areas	Objectives	Use cases
			surveillance	
EDA OCEAN 2020	Sea, Air, Underwater	Surveillance	Maritime situational awareness	Intelligence Surveillance Target Acquisition and Reconnaissance (ISTAR)
		Surveillance	Integrated platform	Recognised maritime picture
H2020 AUTOPILOT	Land	Autonomy	Situational awareness	Autonomous vehicles in a connected environment
		Autonomy	Drive 2 the future	Multi-driving modes
H2020 COREALIS	Land, Sea	Monitoring and management	Port of the future	Port capacity and traffic prediction and management
		Monitoring and management	Land use and urban environment	
		Monitoring and management	Circular economy	
		Surveillance	Situational Awareness	Container Terminal Operational Efficiency
		Surveillance	Port surveillance	
EDA CapTech JAMPAR		Security	Electronic warfare	Non-cooperative target classification and identification (NCTR)
DLR LuFo VI	Land, Sea, Air	Security	Airspace security	Target detection, classification and identification
H2020 CAMELOT	Land, Sea, Air	Surveillance	Border management, security and surveillance	Multi-domain mission system
		Surveillance	Integrated platform	Command Control (C2) and Coordination (C3)
		Surveillance	Situational awareness	Integrated situational picture
H2020 CREST		Surveillance	Law Enforcement Agencies (LEA) operations	Crime and terrorism prediction, prevention, investigation, training
		Autonomy	Situational awareness	Autonomous vehicles in a connected environment
		Surveillance	Situational awareness	Threat risk analysis
		Surveillance	Situational awareness	Multi-domain mission system
		Surveillance	Situational awareness	Target detection, classification and identification
		Surveillance	Situational awareness	Surveillance information sharing and exchange
		Surveillance	Integrated platform	Command Control (C2) and Coordination (C3)
		Surveillance	Situational awareness	Target detection, classification and identification
H2020 RAWFIE	Land, Sea, Air	Surveillance	Situational awareness	Multi-domain mission system
		Surveillance	Integrated platform	Multi-domain mission system
		Surveillance	Border management, security and surveillance	Threat risk analysis
		Surveillance	Border management, security and surveillance	Multi-domain mission system
ESIF AI software	Land, Sea, Air	Safety and Security	Maritime situational awareness	Search And Rescue (SAR)

Project	Domains	Application areas	Objectives	Use cases
prototype for automated drone searches of missing people in the landscape				
H2020 iLEAnet	Land, Sea, Air	Security	Law Enforcement Agencies (LEA) operations	Pre-frontier area monitoring
		Security	Border management, security and surveillance	Illegal immigration and human trafficking detection
H2020 GAUSS	Land, Sea, Air	Safety and Security	Airspace security	Long range and persistent (long endurance) surveillance
		Security	Electronic warfare	Counter jamming, hijacking and signal spoofing
		Surveillance	Situational awareness	UAS Traffic Management (UTM)
		Safety and Security	Maritime situational awareness	Search And Rescue (SAR)
		Monitoring and management	Integrated platform	Command Control (C2) and Coordination (C3)
		Safety and Security	Airspace safety	Safety for UAS and UTM operations
H2020 ALADDIN	Air	Security	Airspace security	Non-cooperative target classification and identification (NCTR)
		Security	Airspace security	Crime and terrorism prediction, prevention, investigation, training
		Security	Situational awareness	Command Control (C2) and Coordination (C3)
H2020 iNGENIOUS	Land, Sea	Monitoring and management	Integrated platform	Command Control (C2) and Coordination (C3)
		Monitoring and management	Port of the future	Port capacity and traffic prediction and management
		Surveillance	Situational awareness	Maritime traffic control
		Surveillance	Situational awareness	Surveillance information sharing and exchange
5G SENSORS@SEA	Sea	Monitoring and management	Port of the future	Port capacity and traffic prediction and management
		Surveillance	Situational awareness	Monitoring platform
		Surveillance	Port surveillance	
iPROCURENet		Security	Security procurement	European security procurement

Table 6 - Domains, application areas, objectives and use cases of project collaborations.

4.1.2 Project collaboration research areas, platforms and sensors

The ROBORDER project collaborations pertained to several research areas, considerably overlapping with ROBORDER interests. The most represented fields were:

- information fusion (28% of project collaboration research areas), in particular data fusion, also including open data; analytics for early warning and target tracking, detection, recognition, and identification; C2 and C3 systems; integration of multidimensional heterogeneous data streams;
- IoT (16%), for example for multimodal information extraction and integration, for smart objects such as autonomous driving vehicles and the integration on smart object taking advantage of 5G networks, blockchain and cloud technologies;
- information sharing (10%) and platform interoperability (8%), for machine-to-machine platforms and heterogeneous multi-modal data, and also with interest in the sharing of confidence and trust information;
- artificial intelligence (8%), including deep learning applications;
- robotics and autonomy (6%), in particular for maritime and aerial environments, and for context aware autonomous mission planning;
- decision support systems, augmented reality, and signal processing (6% each).

Multi-domain mission systems and visual analytics were also topics of interest. The ROBORDER project collaboration research areas are visualised in Figure 20.

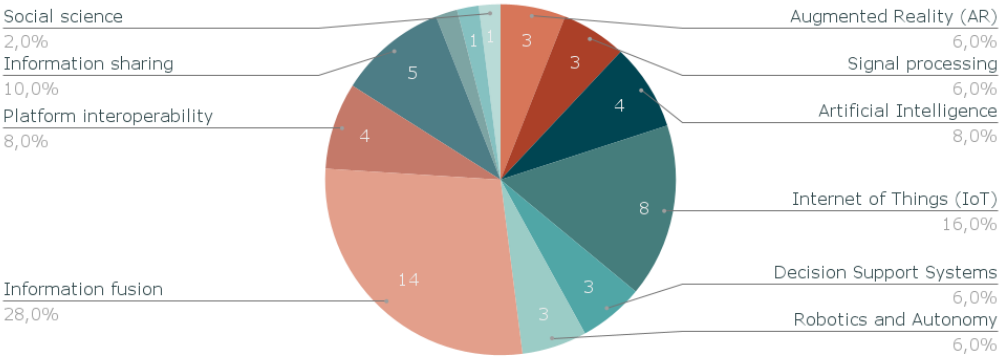

Figure 20 - Research areas of ROBORDER Project collaborations.

Like ROBORDER, the collaboration projects used a plethora of platforms and sensors, which can be overviewed in Figure 21. Unmanned systems and vehicles were the most recurring (34,5%), together with sensors for surveillance (27,6%) and heterogeneous multi-modal sensors (24,1%). Autonomous driving vehicles, web and social media and open sources of information were also addressed by other four projects.

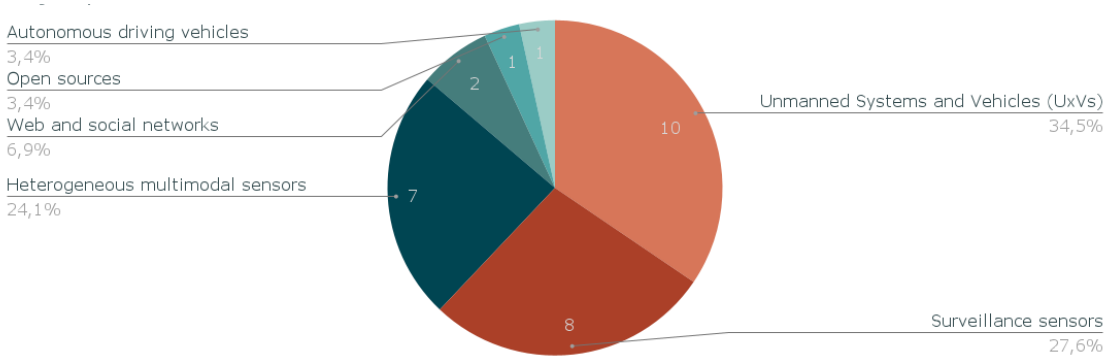

Figure 21 - ROBORDER Project collaborations: platforms, sensors, and sensor data.

The project collaboration research areas, with the detailed techniques applied, are specified in Table 7 with platforms and sensors.

Project	Research areas	Research techniques (details)	Platforms and sensors	Platforms sensors data (details)
H2020 ARESIBO	**Augmented Reality (AR)**	*Mobile Augmented Reality (AR)*	**Unmanned Systems and Vehicles (UxVs)**	*Unmanned Surface Vehicles (USVs)*
		Extended Reality		*Unmanned Ground Vehicles (UGV)*
	Signal processing	*Wearables telecommunications*		*Unmanned Aerial Vehicles (UAVs)*
	Artificial Intelligence			*Unmanned Underwater Vehicles (UUVs)*
	Internet-of-Things (IoT)			*Swarm robotics*
	Decision Support Systems	*Threat risk analysis*		
		Cloud-based Decision-support services and tools		
	Robotics and Autonomy	*Context-aware Autonomous missions planning*		
		Swarm Robotics		
		Technological demonstrator		
	Information fusion	*Data fusion*		
H2020 ANDROMEDA	**Information fusion**	*Data exchange model*	**Surveillance sensors**	
	Decision Support Systems	*Decision support services*		
		Data analytics		
		Maritime CISE Model		
H2020 CONNEXIONs	**Augmented Reality (AR)**	*3D scene reconstruction*	**Heterogeneous multimodal sensors**	
		(Crime-scene) Simulation		
	Internet-of-Things (IoT)	*Multimodal information extraction and integration*		
	Platform interoperability	*Heterogeneous multimodal data*		
H2020 RANGER	**Artificial Intelligence**	*Machine/deep learning*	**Surveillance sensors**	*Radar*
	Information fusion	*Vessel tracking, detection, recognition, and identification*		
		Maritime CISE Model		
		Early warning		
H2020 COMPASS 2020	**Information fusion**	*Data fusion*	**Unmanned Systems and Vehicles (UxVs)**	

Project	Research areas	Research techniques (details)	Platforms and sensors	Platforms sensors data (details)
	Information sharing			
EDA OCEAN 2020	**Information fusion**		**Unmanned Systems and Vehicles (UxVs)**	*Unmanned Surface Vehicles (USVs)*
				Unmanned Aerial Vehicles (UAVs)
				Unmanned Underwater Vehicles (UUVs)
H2020 AUTOPILOT	**Robotics and Autonomy**	*Large-Scale Pilots (LSPs)*	**Heterogeneous multimodal sensors**	*Open data*
	Internet-of-Things (IoT)	*Autonomous driving vehicles*	**Unmanned Systems and Vehicles (UxVs)**	*Autonomous driving vehicles*
	Information fusion			
H2020 COREALIS	**Internet-of-Things (IoT)**	*5G networks*	**Heterogeneous multimodal sensors**	
	Information fusion	*Data analytics*		
EDA CapTech JAMPAR	**Information fusion**	*Non-cooperative target classification and identification (NCTR)*	**Surveillance sensors**	*Passive Radar*
	Signal processing	*Jammer signals*		*Jammer signals*
DLR LuFo VI	**Signal processing**	*Detection of small air target*	**Surveillance sensors**	*Passive bistatic radar (PBR) systems*
				Small air targets
				Radar
			Unmanned Systems and Vehicles (UxVs)	*Unmanned Aerial Vehicles (UAVs)*
H2020 CAMELOT	**Information fusion**	*integrated situational picture*	**Unmanned Systems and Vehicles (UxVs)**	
		Modular and scalable Command and Control (C2)	**Surveillance sensors**	*Optical*
	Platform interoperability	*Standardisation*		*Radar*
		integrated operational platform		*Infrared (IR)*
H2020 CREST	**Information fusion**	*Threat risk analysis*	**Web and social networks**	*Surface/Deep/Dark Web*
		Multidimensional heterogeneous data stream integration and correlation		*Social media*

Project	Research areas	Research techniques (details)	Platforms and sensors	Platforms sensors data (details)
		Monitoring, tracking, and analytics		*Heterogeneous data stream*
		Distributed operational Command and Control (C2)	**Unmanned Systems and Vehicles (UxVs)**	*Wearable sensors*
	Visual analytics	*Automatic early warning*	**Heterogeneous multimodal sensors**	*Surveillance cameras*
		Automated detection, identification, assessment, fusion, and correlation of digital evidence	**Surveillance sensors**	
	Augmented Reality (AR)	*Interactive augmented reality environments*		
	Information sharing	*Confidence and trustworthiness of information sharing*		
	Internet-of-Things (IoT)	*Blockchain technologies*		
H2020 RAWFIE	**Internet-of-Things (IoT)**	*Everything as a Service (EaaS)*	**Unmanned Systems and Vehicles (UxVs)**	*Unmanned Ground Vehicles (UGVs)*
		Cloud		*Unmanned Aerial Vehicles (UAVs)*
	Robotics and Autonomy	*Vehicular aerial and maritime environments*		*Unmanned Surface Vehicles (USVs)*
	Robotics and Autonomy			
ESIF AI software prototype for automated drone searches of missing people in the landscape	**Information fusion**	*Online Data fusion*	**Unmanned Systems and Vehicles (UxVs)**	
	Artificial Intelligence			
H2020 GAUSS	**Information fusion**	*Positioning and inertial data fusion*	**Unmanned Systems and Vehicles (UxVs)**	*Unmanned Aircraft Systems (UAS)*
	Information sharing	*Communications encryption*		*RPAS operations*
	Multi-domain Mission Systems	*Land and Maritime Missions*		*VLL operations*
			Surveillance sensors	*Galileo-EGNOS*
				Multi-frequency and multi-constellation
				ADS-B
				RPAS operations
				VLL operations
H2020 ALADDIN	**Platform interoperability**	*System of System*	**Surveillance sensors**	*2D/3D paired radars*

Project	Research areas	Research techniques (details)	Platforms and sensors	Platforms sensors data (details)
	Information fusion	*Data fusion*	**Heterogeneous multi-modal sensors**	*Optro and Thermal panoramic imaging*
	Artificial intelligence	*Deep learning*		*Acoustic sensors*
			Open sources	*Open data*
H2020 iNGENIOUS	**Platform interoperability**	*Machine-to-Machine (M2M) Platforms*	**Heterogeneous multimodal sensors**	*No open data*
	Internet-of-Things (IoT)	*M2M Interoperability Layer*	**Autonomous driving vehicles**	*Anonymized data*
	Information fusion			
	Information sharing			
	Decision Support Systems			
5G SENSORS@SEA	**Internet-of-Things (IoT)**	*Smart objects/sensors (Narrowband IoT NB-IoT)*	**Heterogeneous multimodal sensors**	*No open data*
	Information sharing			
iPROCUREnet	**Social science**	*Training, workshops and conference*	**Web and social networks**	*iProcureNet toolbox*

Table 7 - ROBORDER project collaborations: research areas, platforms and sensors.

4.2 Project collaboration activities

The numerous project collaborations facilitate ROBORDER staying at the cutting-edge of innovation in the scientific and technical areas of interest for the project, and boosted the exploitation of project results. Figure 22 shows the distribution of the different activity types among the forty-three reported activities. Collaboration activities mostly concerned knowledge transfer and exchange (57,1%) through project participation, raising opportunity for joint organisation of events like project workshops, demonstrations and meetings (14,3%), or joint participation to events (11,9%). In other cases the collaboration activities concerned the provision of expertise (9,5%), the participation to project user's network and other networking activities (7,1%).

An exemplar case of result up-take that brought a substantial innovation during ROBORDER and which was further exploited after the project conclusion is the M2M platform developed for the port of Livorno. This platform was used first in AUTOPILOT, then in ROBORDER and COREALIS where it dedicated micro-services were developed. In particular, ROBORDER advanced the interoperation of photonic based radars with the Livorno Port Monitoring and Control Application. The tested platform, which is part of the ROBORDER exploitable results, will be further used in INGENIOUS and SENSORS@SEA were dedicated micro-services will be developed (for the integration of smart objects for container tracking and to further advance interoperability). The comprehensive outcome is a cut edge IoT platform for efficient and secure port monitoring and management, which is developed within the initiative "Port of the future".

A comparable approach is adopted for the refined development of a customised interoperable distributed simulators and associated developments (mission specification and editor, approach for the definition of performance indicators and models, simulation output viewer), which were shared among ROBORDER, ARESIBO, COMPASS, and OCEAN 2020. The exchange with ARESIBO was particularly intense due to the commonalities in the two projects and the high number of partners shared by the two projects.

Noticeable examples of results transferred to ROBORDER were the approach for generic UxV mission specification, the communication architectural components originally developed in RAWFIE, which were also included in the EC innovation radar for IoT EaaS platforms. In addition, the experience acquired in RAWFIE for end user's evaluation was leveraged to prepare the end user evaluation questionnaire used in the first ROBORDER demonstration.

Significant transfers of knowledge that exploited ROBORDER results were the transition of UxV mission definition to GAUSS; the interface with the ground control station, the UGV prototypes and the autonomous navigation systems for UGV developed in ROBORDER and ARESIBO and transferred to CREST; the augmented reality (AR)-based component for commanding UxV and the AR presentation of situational awareness component exchanged among ROBORDER and ARESIBO.

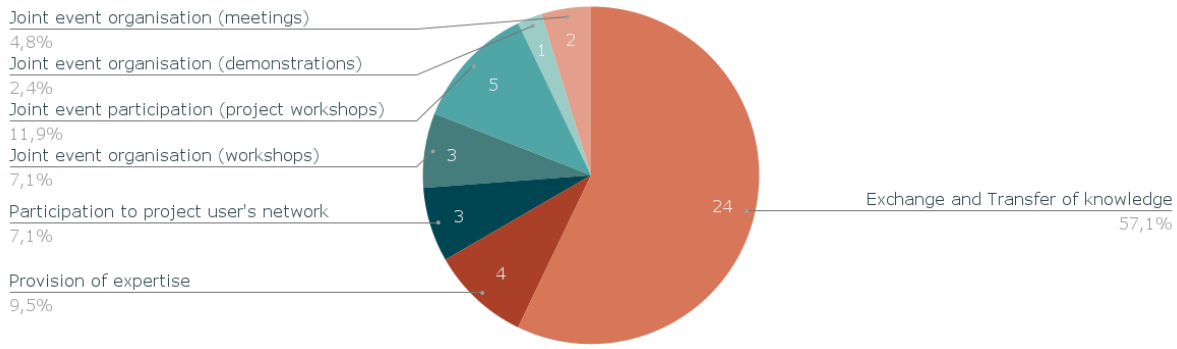

Figure 22 - ROBORDER: Types of project collaboration activities.

The project collaboration activities per collaborating project are reported in Table 8. The table specifies the type of collaboration activity and its detailed description, together with the partners participating to the collaboration.

Project	**Reference Partner**	**Activity type**	***Activity description***
H2020 ARESIBO	CERTH	**Exchange and Transfer of knowledge**	*Similar objectives for the technical developments were obtained: Detections and object tracking based on visual and thermal camera feeds, Cognitive services, Data models, Integration activities for establishing the core system*
	CERTH	**Provision of expertise**	
	CMRE	**Exchange and Transfer of knowledge**	*Assets kinematic and sensor performance models, mission editor and structure. Simulation output viewer*
	UoA	**Exchange and Transfer of knowledge**	*Mission definition. AR-based commanding of UxV. Data fusion. AR-presentation of Situational awareness components.*

Project	Reference Partner	Activity type	*Activity description*
	UoA	**Exchange and Transfer of knowledge**	*NKUA, as the technical coordinator of the ARESIBO project, participates in all the foreseen project events. Over the last year, NKUA has also led the preparation of the live demonstration that took place in January 2021 during the ARESIBO project review meeting. During the same event, NKUA has also highlighted connections between ROBORDER and ARESIBO in terms of the design principles and the architecture of the two projects.*
	ROB	**Exchange and Transfer of knowledge**	*UGV prototypes. Ground control station for UGV. Autonomous navigation systems for UGVs*
	VTT	**Exchange and Transfer of knowledge**	*Augmented reality for border security. Especially for C2 and field officer*
H2020 ANDROMEDA	CERTH	**Participation to project user's network**	*CERTH joined the ANDROMEDA's "Users Network".*
	CERTH	**Joint event organisation (project workshops)**	*ROBORDER and ANDROMEDA jointly participated in MSE2019 (Mediterranean Security Event) which took place in Crete on Oct. 29th and 30th (https://mse2019.kemea-research.gr/) and where both projects exchanged technical opinions for common objectives and implementations.*
	CERTH	**Joint event participation (project workshops)**	*ROBORDER participated in ANDROMEDA's end-user workshops where project outcomes and targets were presented to a wider audience. Participation to 1st Andromeda Workshop, online - GoToWebinar, 28-29/09/2020*
	CERTH	**Exchange and Transfer of knowledge**	*Consortia exchanged knowledge for relevant technologies.*
H2020 CONNEXIONs	CERTH	**Provision of expertise**	*CERTH, acted as coordinator in both projects and was majorly involved in technical developments. Knowledge acquired from the project has been exploited in particular components both at service and system level. During the upcoming period, the joint workshops (demonstrations, meetings etc.) will also be organized proving the strong collaboration and relativity*
	CERTH	**Joint event organisation (workshops)**	
	CERTH	**Exchange and Transfer of knowledge**	
H2020 RANGER	CERTH	**Participation to project user's network**	*CERTH participated in the last RANGER demonstration. To this end, CERTH acquired knowledge about the organization of a demonstration and all the requirements that may be involved*
	CERTH	**Joint event organisation (demonstrations)**	
	CERTH	**Joint event participatio**	*Participation in RANGER's final workshop that took place in Crete on Nov. 20th, 2019*

Project	Reference Partner	Activity type	*Activity description*
		n (project workshops)	
H2020 COMPASS 2020	CMRE	**Exchange and Transfer of knowledge**	*Mission editor. Simulation output viewer. Approach to the definition of KPIs*
	CERTH	**Participation to project user's network**	*Collaboration between the projects end-user groups to identify common operational needs. Discussion among end users to identify existing needs in border management and technologies*
	CERTH	**Exchange and Transfer of knowledge**	*Request for access to D4.2 (regarding EUCISE ontologies). Request to access the work done within the context of ROBORDER on CISE ontologies. (Declassification of the document pending at the moment). Discussion among end users to identify existing needs in border management and technologies. Discussions on how to develop and compile appropriate KPI metrics*
H2020 OCEAN 2020	CMRE	**Exchange and Transfer of knowledge**	*Mission editor. Simulation output viewer. Extension of the simulated ocean environment to land.*
H2020 AUTOPILOT	CNIT, AdSP-MTS	**Exchange and Transfer of knowledge**	*Development of M2M Platform interoperability, experience leveraged for ROBORDER. During the AUTOPILOT project, comparison and interoperability activities were carried out between different M2M platforms available that where compliant with the oneM2M standard. At the end of the project, this experience was used to create an M2M platform dedicated to the port of Livorno. In the ROBORDER (and COREALIS) project, the platform is extended with dedicated microservices, exploiting the peculiarities of scalability and interoperability*
H2020 COREALIS	CNIT, AdSP-MTS	**Exchange and Transfer of knowledge**	*Developing Cargo Terminal Activity Use Case. Based on the experience of AUTOPILOT project, the M2M compliant platform is extended with specific microservices and an exchange of knowledge is carried out with ROBORDER*
CapTech JAMPAR	FHR	**Provision of expertise**	*Analysis and definition of system architecture. Design, development and demonstration of a passive receiver front-end that meet requirements.*
DLR LuFo VI	FHR	**Provision of expertise**	*Analysis and definition of system architecture. Design, development and demonstration of a passive receiver front-end that meet requirements.*
H2020 CAMELOT	HMOD	**Joint event organisation (meetings)**	*RAWFIE collaboration meeting with existing H2020 Security projects and initiatives. Joint meeting within ROBORDER, RAWFIE, CAMELOT* *Athens, June 08, 2018* *Venue: University of Athens, Dpt. Of Informatics and Telecommunications, Room A56* *Topics: Technical Overview, Design – Implementation – Integration* ** Project scope* ** Objectives* ** Design and architecture* ** Data models* ** Current status*
	CERTH	**Joint event participation (project workshops)**	
	CERTH	**Exchange and**	*Exchange of knowledge on UxVs and sensors for border surveillance*

Project	Reference Partner	Activity type	*Activity description*
		Transfer of knowledge	
H2020 CREST	COPT	**Exchange and Transfer of knowledge**	*The Ground control station (GCS) to ROBORDER platform interface developed in ROBORDER is shared with CREST, where it is adapted to the CREST platform and other tasks: the platform is used for mission planning and deployment, and to transfer live and status data from drones to the platform.*
	ROB	**Exchange and Transfer of knowledge**	*UGV prototypes. ground control station for UGV, autonomous navigation systems for UGVs*
H2020 RAWFIE	UoA	**Exchange and Transfer of knowledge**	*Specialization of key RAWFIE elements like the Domain Specification Language (DSL) Experiment Description Language (EDL) to the ROBORDER needs. Adoption of architectural components like KAFKA middleware for communication among platform elements (RAWFIE Innovation Item – EC Innovation Radar for integration of within Internet-of-Things EaaS). Generic commanding of the UxV irrespective of the UxV technology. The end user evaluation questionnaire developed for the first ROBORDER demonstration (Portugal, Nov 2020) was built on the experience gained by UoA in RAWFIE*
	UoA	**Joint event organisation (meetings)**	*RAWFIE collaboration meeting with existing H2020 Security projects and initiatives. Joint meeting within ROBORDER, RAWFIE, CAMELOT (cf. CAMELOT activities)*
ESIF AI software prototype for automated drone searches of missing people in the landscape	EASS	**Exchange and Transfer of knowledge**	*Application of AI technologies towards improving internal security. Cross Fertilisation with national industry and security institutions*
H2020 iLEAnet	CERTH	**Exchange and Transfer of knowledge**	*Knowledge transfer to the end users of iLEAnet's practitioners in regard to new technologies that are not available to them via the current market and how they can take advantage of them.*
	CERTH	**Joint event participation (project workshops)**	*"iLEAnet Public Workshop on Innovative technologies for border management" 4-5 November 2020*
	ALL	**Exchange and Transfer of knowledge**	*"iLEAnet's uptake webinar on ROBORDER's exploitation by border authorities" 30 March 2021* https://mklab.iti.gr/roborder/lib/exe/fetch.php?media=various:promotional_leaflet.pdf
H2020 GAUSS	EVADS	**Exchange and Transfer of knowledge**	*Mission definition. The operational experience acquired by EVADS in the T6.4 ROBORDER Demonstration was used in the definition of the flight plans and operability of the use cases of the Second Demonstration of GAUSS Project.*
H2020 ALADDIN	PJ	**Joint event participatio**	*PJ participated in the regular internal project activities as workshops/trainings on ALADDIN system.*

Project	Reference Partner	Activity type	*Activity description*
		n (project workshops)	
H2020 iNGENIOUS	CNIT, AdSP-MTS	**Exchange and Transfer of knowledge**	*Development of a M2M Interoperability Platform/Orchestrator, for the communication and data exchange among different Port Agencies and Authorities. The orchestrator will guarantee interoperability among different heterogeneous M2M platforms from different vendors and having different communication standards/protocols (e.g., oneM2M, etc...). For the development of INGENIOUS, it will be fundamental the expertise matured within ROBORDER during the integration/interoperability activities between the oneM2M Monitoring and Control Application (Moni.C.A) in the Port of Livorno and the ROBORDER system.*
5G SENSORS @SEA	CNIT, AdSP-MTS	**Exchange and Transfer of knowledge**	*Integration of satellite and terrestrial communications for real-time monitoring and tracking of containers within deep sea and terrestrial domain. Based on the experience of AUTOPILOT and ROBORDER projects, the M2M compliant platform is further extended with specific microservices.*
iPROCURE net	CERTH	**Exchange and transfer of knowledge**	*Presentation of ROBORDER system to iPROCUREnet partners, National POC and other invited iProcure partners. Established buyers group.*
	CERTH	**Joint event organisation (workshop)**	

Table 8 - ROBORDER Collaboration activities.

As illustrated in Figure 23, most of technical ROBORDER work packages are associated to collaboration activities, in particular: WP6 Demonstration and evaluation which is associated to 27% of activities; WP5 Integration of the ROBODER platform for the remote assessment of border threats and WP4 Command and control functionalities, which are associated to 21,6% of activities each; and WP3 Detection and identification of border related threats (10,8%).

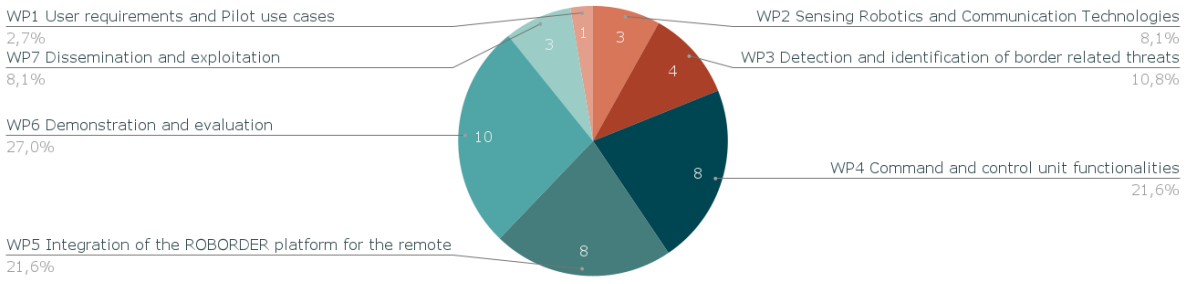

Figure 23 - Collaboration activities in ROBORDER work packages.

Among tasks, the most represented are Task 4.3 Autonomous resource task coordination and Task 5.4 ROBORDER System integration (seven collaboration activities each); Task 6.3 Preparation and implementation of test-plans as simulated exercises (six collaborations); Tasks 4.4 CISE compliant common representation model and semantic reasoning and Task 6.1 End-user evaluation plans and methodology (five collaboration activities); Task 6.4 Demonstration and evaluation for land border threat detection (four collaborations). Figure 24

gives a complete overview of the distribution of project collaborations among ROBORDER tasks.

Figure 24 - Collaboration activities in ROBORDER tasks

5 Additional activities and progress with respect to second period review

In the last reporting period (from July 2020, from the second mid-term project review), six new project collaborations (iLEAnet, GAUSS, ALADDIN, iNGENIOUS, SENSORS@SEA, iPROCUREnet) have been added to the report, and four standards have been included.

Meanwhile, one project proposal (EMERALD) have been rejected.

Recent activities associated to standardisation include:

- The participation to the 5th CISE Stakeholder group meeting, organised by EMSA and on 6-7 October 2020
- The implementation of the MCDS standard for UGV GCS

Recent project collaboration activities include:

- Participation to the 1st ANDROMEDA workshop, held on 28-29 September 2020.
- Request to for knowledge exchange with COMPASS 2020 on D4.2
- Participation to the “ILEAnet Public Workshop on Innovative technologies for border management" 4-5 November 2020
- Participation to the live demonstration of ARESIBO in January 2021
- Adaptation of the RAWFIE end user’s evaluation questionnaire to the user evaluation within the first ROBORDER demonstration which was held in Portugal in November 2020.
- Participation to the ““iLEAnet's uptake webinar on ROBORDER's exploitation by border authorities” 30 March 2021 https://mklab.iti.gr/roborder/lib/exe/fetch.php?media=various:promotional_leaflet.pdf”

- Presentation of the ROBORDER system to iProcureNet partners.

6 Conclusion

This document reported on the standardisation and project collaboration activities that supported the execution of the ROBORDER project and the development of its multi-domain border security platform. Standardisation and project collaboration activities have been reported and analysed in this document, illustrating their relevance with respect to ROBORDER key applications and research topics, and their distribution among project partners and tasks.

ROBORDER partners adopted nineteen different standards, guidelines, best practices and information models, which enabled platform interoperability, guided the operation of UxVs missions and system, and the platform evaluation. Contributions to standards ranged from the enrichment of existing models and frameworks, to the development of a UxV mission specification language, and included the participation to a global standardisation initiative for interoperable automated machine-to-machine data exchange and the integration of networked sensorised devices (IoT). Overall, twenty-tree standardisation activities were reported.

Twenty project collaborations, distributed along duration of the project, supported project innovations facilitating the transfer of the knowledge across projects, especially for surveillance, monitoring and security in multi-domain environments. These projects included fifteen other EU Horizon 2020 projects, and mainly involved European countries. These pertained to research areas overlapping with ROBORDER interests, in particular information fusion, Internet-of-Things, information sharing, platform interoperability, artificial intelligence robotics and autonomy, decision support systems, augmented reality and signal processing.
In total, forty-two project collaborations activities have been reported, mostly concerning knowledge transfer and exchange.

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Acknowledgment

This document has been prepared with the precious contribution and collaboration of the ROBORDER partners mentioned in the document as the reference partners for standardisation and project collaboration activities.

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Appendix I. Methodology for data collection and preparation

Preliminary information on standardisation activities and project collaboration was collected by CMRE during executive board meetings, extracting the relevant information from partner presentations on project task descriptions. This collected information was then integrated with the use of structured focused surveys compiled by project partners and revised with CMRE in dedicated one-to-one meetings (per partner). The structured surveys are described in the following sections.

Survey questions on standards at large

Partners have been requested to provide detailed description of any standard at large (to include standards, best practices, data or information exchange models, protocols, vocabularies, ontologies, guidances, doctrines, specifications, etc.) they used or contributed to in the execution of ROBORDER tasks. For each standard define as above, each partner was requested to provide:

- the complete reference to the standard, i.e., the complete standard title, short name or acronym, version;
- the standard application scope and objectives;
- the ROBORDER work package and task were the standard was used, or defined;
- the type of standardization activity the partner was contributing to, either alignment to standard or contribution to standardization.

In addition, for standard proposals or under definition, partners were requested to provide an expected time for their adoption.

The required information was collected with the help of the survey Table 9, including examples by CMRE.

Partner	Standard	Full reference	Scope, objective	ROBORDER WP & Task	Type of Activity	Expected Timeline
CMRE	High Level Architecture (HLA)	IEEE 1516-2010	Interoperability, federation of distributed simulations	WP6 T6.1 T6.3	Alignment to standard	

Table 9 - Request of information on standards (with example)

Survey questions on standardisation committees

In addition, partners were requested information on the standardization committees, working and technical groups they were participating, whose topics and objectives were of interest for ROBORDER. Partners were requested to provide:

- A reference title, name, website of the standardization committee or working group;
- The scope and objectives of the committee or working group;
- The ROBORDER work package and task related to the committee;
- The type of contribution, either silent participation, contribution, coordination, etc.
- Reference to events related to the standardization committee or working group, like open meetings or presentation, workshops, seminars, standardization conferences, etc.

- Temporal information on the duration of the collaboration with the committee or working group, such as the starting date, the frequency of the meetings. For new or upcoming activities, a planned starting date was requested.

The required information was collected with the help of the survey Table 10. Table 10 includes an example of the activities executed by CNIT.

Partner	Standardization committee working group	Website	Scope, objective	ROBORDER WP & Task	Type of Activity	Events	Timeline
CNIT	Technical Committee Smart Machine-to-machine communications SMARTM2M	https://www.etsi.org/committee/smartm2m	developing standards to enable M2M services and applications	WP3 T3.2 "Identification and Tracking of Illegal activities" WP5 T5.4 "ROBORDER System Integration"	Participation	AUTOPILOT TESTFEST October - November 2019 https://autopilot-project.eu/event/testfest-results-presentation-workshop/	

Table 10 - Request of information on standardisation committees

Survey questions on standardisation project collaborations

ROBORDER partners have been requested to describe the projects collaboration that their institute, company or lab carried out which relates to the execution of ROBORDER, and the collaboration activities associated to them. For each project, partners were requested to provide:

- The project name, website, the starting and ending date;
- the focus areas and topics;
- the ROBORDER work packages and tasks were this collaboration was carried out;
- the status of the collaboration (concluded, ongoing, planned, tentative);
- any record or planned activity supporting the collaboration, including joint publications, joint organization of workshops and events such as meetings, webinars, scientific challenges, demos, public mention in the news (e.g., interviews, articles in newspapers, radio recording).

The required information was collected with the help of the survey table reported in Table 11, which includes as example one of the activities executed by CMRE.

Partner	Project	Website	Project dates	Topics	ROBORDER WP & Task	Status	Collaboration activity
CMRE	COMPASS 2020 Coordination Of Maritime	http://www.compass2020-project.eu/	May 2019 - Oct 2020	Maritime surveillance operations,	WP 6 T6.1, T6.3	ONGOING	

	Assets for Persistent and Systematic Surveillance			unmanned vehicles UxVs […]			

Table 11 - Request of information on collaborations with other projects.