EURMARS

An advanced platform to improve the EUROpean Multi Authority borderR Security efficiency and cooperation.

Final Publishable Report

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101073985

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Executive Summary

The EURMARS Project (An advanced surveillance platform to improve the EURopean Multi-Authority bordeR Security efficiency and cooperation, Grant Agreement No. 101073985) was funded under the Horizon Europe programme as an Innovation Action (IA). Running from October 2022 to September 2025, EURMARS united 18 partners from 13 countries, combining expertise from industry, research institutions, SMEs, practitioners, and EU agencies. This diverse consortium ensured that project outcomes were both scientifically robust and operationally relevant.

EURMARS tackled the growing complexity of security threats in the maritime domain, including irregular migration, trafficking, illegal fishing, and other cross-border challenges. In line with EU policy frameworks such as the European Union Maritime Security Strategy, EUROSUR, and CISE, the project responded to the need for closer collaboration among national, regional, and EU-level authorities. Its vision was to design, develop, and validate a flexible, interoperable surveillance platform integrating high-altitude platforms, UAVs, satellite imagery, coastal sensors, and AI-based risk analysis tools into a single joint capability.

Through advanced sensing, real-time data fusion, risk assessment, and visualization, EURMARS enhanced situational awareness, operational efficiency, and multi-authority cooperation. The platform was validated in three large-scale pilot demonstrations in Cyprus, the United Kingdom, and Bulgaria, providing concrete proof of its effectiveness in real operational environments and strengthening cooperation among border and maritime authorities.

Among its key achievements, EURMARS successfully developed a fully integrated surveillance platform that combines diverse sensing technologies with advanced analytics and decision support capabilities. The project established a secure and interoperable architecture enabling seamless data exchange across multiple authorities, thereby enabling secure, efficient collaboration. In addition, EURMARS created open benchmark datasets and contributed to international standards, supporting transparency and reusability of its results. All developments were accompanied by comprehensive ethical, privacy, and legal assessments to ensure responsible technology adoption and full compliance with European regulatory and societal expectations.

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EURMARS also produced a strong scientific and societal footprint. Results were disseminated through peer-reviewed publications, workshops, international conferences, and policy dialogues, contributing to both the research and practitioner communities. A dedicated dissemination and exploitation strategy enhanced visibility, while clustering with related EU projects and participation in high-level European events maximised impact and ensured sustainability.

By combining technical innovation, operational validation, and ethical foresight, EURMARS demonstrated a scalable and sustainable approach to European maritime surveillance. Its results will continue to support the EU's objectives for integrated border management, enhanced situational awareness, and strengthened multi-authority cooperation, ensuring lasting impact beyond the project's lifetime.

Glossary of Terms

- AI: Artificial Intelligence
- BM: Border Management
- AIS: Automatic Identification System
- CISE: Common Information Sharing Environment
- DSS: Decision Support System
- EUROSUR: European Border Surveillance System
- IUU: Illegal, Unreported, and Unregulated (fishing)
- LLM: Large Language Model
- MDFP: Multimodal Data Fusion Platform
- RAT: Risk Assessment Tool
- SAR: Synthetic Aperture Radar
- UAV: Unmanned Aerial Vehicle

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Project Overview

Security risks and threats in the maritime domain are becoming increasingly complex and dynamic. Within the EU, irregular migration flows, human trafficking, and smuggling activities have significantly increased in recent years, while drug and arms trafficking and illegal, unreported, and unregulated (IUU) fishing continue to pose persistent challenges. According to the FRONTEX Risk Analysis for 2021 report, these trends are expected to intensify, creating a pressing need for enhanced maritime security and surveillance.

At the same time, European maritime border management remains a highly multifaceted task. It involves the cooperation of diverse authorities, including coast guards, border guards, customs, police, fisheries, environmental protection agencies, and maritime safety entities. These actors often operate under different mandates, responsibilities, and capacities. As a result, there are frequent coordination gaps and even operational overlaps, which limit overall effectiveness. Addressing this challenge requires both improved interoperability of technical systems and stronger collaboration between institutional stakeholders.

The European Union Maritime Security Strategy, together with initiatives such as EUROSUR and CISE, has emphasized that closer collaboration between authorities at national, regional, and EU levels is crucial to enhance situational awareness and operational efficiency. However, achieving this in practice requires novel approaches that combine advanced sensing technologies, integrated platforms, and mechanisms for secure information exchange and joint decision-making.

EURMARS was designed to meet this need. Its vision is to expand current security and risk assessment practices by developing, deploying, and evaluating a secure, multitasking surveillance platform that integrates heterogeneous technologies into a unified capability. High-altitude platforms, satellite imagery, unmanned systems, and ground-based sensors are clustered within an open architecture, enabling seamless fusion of data sources and joint operations across authorities. The system is designed to improve detection capabilities, support structured decision-making, and enhance operational efficiency in sensitive maritime and border environments.

The EURMARS concept is illustrated in Figure X, which demonstrates how diverse sensing technologies, data fusion, and AI analytics are combined within the platform to address

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real-world scenarios. These include search and rescue, monitoring suspicious vessel activities, identifying unusual vessel trajectories, and preventing smuggling or trafficking operations.

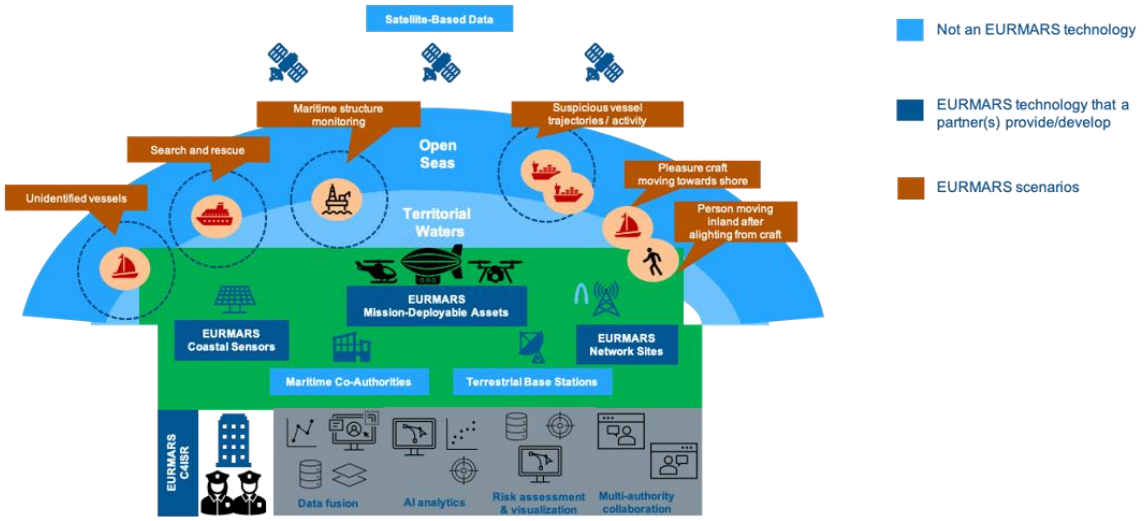

Figure 1 EURMARS Overall Concept

By clustering multiple technologies into an open, interoperable architecture, EURMARS builds on lessons learned from previous initiatives while assimilating the operational knowledge of stakeholders and their practices, including CISE. The platform exploits state-of-the-art advances in AI, risk assessment, and visualization, and has undergone extensive technical and user acceptance testing. Ethical and legal impact assessments further ensured that the system aligns with European values and regulatory frameworks.

Through this integrated approach, EURMARS not only strengthens operational readiness for maritime security authorities but also delivers a policy-relevant outcome: a platform that supports multi-authority cooperation, improves situational awareness, and contributes directly to the EU's strategic vision for border and maritime security.

Results & Objectives

The EURMARS project set out to address the growing challenges of maritime border security by designing, developing, and validating an advanced integrated surveillance platform. Its overarching objective was to deliver a flexible and interoperable system capable of enhancing situational awareness and supporting decision-making across multiple authorities and operational domains.

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A key achievement of the project has been the development of the EURMARS Integrated Platform, which combines high-altitude sensor technologies, multimodal data fusion, artificial intelligence, and a decision support system (DSS) into a unified surveillance capability. The platform was designed on the basis of validated stakeholder requirements, with end-user needs systematically identified, analyzed, and prioritized throughout the project.

The system architecture was developed to ensure secure and interoperable operations, enabling seamless data exchange across different authorities and systems. Advanced components for data analytics, risk assessment, and visualization were integrated to provide accurate analysis, effective alarming mechanisms, and intuitive visualization interfaces, thereby supporting operational efficiency.

The platform and its components were validated in real-life operational scenarios through three large-scale pilot demonstrations in Cyprus, the United Kingdom, and Bulgaria. These pilots provided proof of concept, operational maturity, and direct feedback from end users, ensuring that the system aligns with real-world needs and challenges.

In parallel, ethical, legal, and societal implications were assessed through a dedicated foresight report, ensuring that EURMARS outcomes are not only technically advanced but also legally compliant and socially responsible. The project also contributed to the wider research and innovation community by producing open benchmark datasets and supporting the advancement of international standards in the field of maritime surveillance.

EURMARS Consortium

The EURMARS consortium unites a diverse set of actors from across Europe, ensuring that innovation is closely tied to operational needs and policy priorities. This composition has been a defining strength of the project, enabling collaboration across the full research and innovation chain.

Industry expertise was provided by European Dynamics (ED), the project coordinator, and Thales Alenia Space France (TASF). Together, these partners advanced the common platform concept, supported standardisation efforts, and prepared pathways for the future commercialisation of project results through international networks.

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Research organisations formed the scientific backbone of EURMARS. Austrian Institute of Technology (AIT), Technical Research Centre of Finland (VTT), Centre of Excellence for Space Sciences and Technologies (SPACE-SI), Bulgarian Defence Institute (BDI), University of Reading (UREAD) and The French Aerospace Lab (ONERA) delivered advances in sensing, fusion and analytics. Their work pushed the state of the art in image and video analysis and ensured that technological innovations were grounded in academic and applied research excellence.

The consortium also included dynamic SMEs, Geosystems Hellas (GSH), Hardware and Software Engineering (HSE), SKYLD Security and Defence, and Trilateral Research (TRI). These partners contributed significantly to sensor development and technology integration, while also playing a key role in dissemination, communication, and the integration of ethical, legal and data protection considerations into EURMARS solutions.

Practitioners were actively represented by national authorities and operational end users, including Glavna Direktsia Granichna Politsia (GDBP), the General Maritime Directorate (GMD), the Romanian Border Police (RBP), and the UK Home Office (UKH). Their participation ensured that user needs were specified from the outset and that prototypes were tested and validated in real-world operational environments.

Finally, the consortium was strengthened by the participation of the European Union Satellite Centre (SATCEN), which brought unique expertise in space-based data for security applications. SATCEN ensured that EURMARS outputs were communicated effectively to relevant EU stakeholders and directly supported decision-making processes at the European level.

Together, this balanced consortium composition guaranteed that EURMARS results were not only technologically advanced, but also ethically sound, operationally validated and positioned for sustainability and impact beyond the lifetime of the project.

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Figure 2 EURMARS Consortium

Technical Solutions

The EURMARS project has developed and validated a comprehensive, multi-layered surveillance framework designed to strengthen maritime border management through the integration of heterogeneous sensing technologies, advanced data processing, and decision support systems. The technical solutions developed combine coastal and aerial sensing, satellite-based monitoring, and multimodal data fusion, supported by AI-driven risk assessment and decision-making tools. Collectively, these innovations address the growing complexity of maritime security risks and provide authorities with enhanced situational awareness, operational efficiency, and multi-authority cooperation capabilities.

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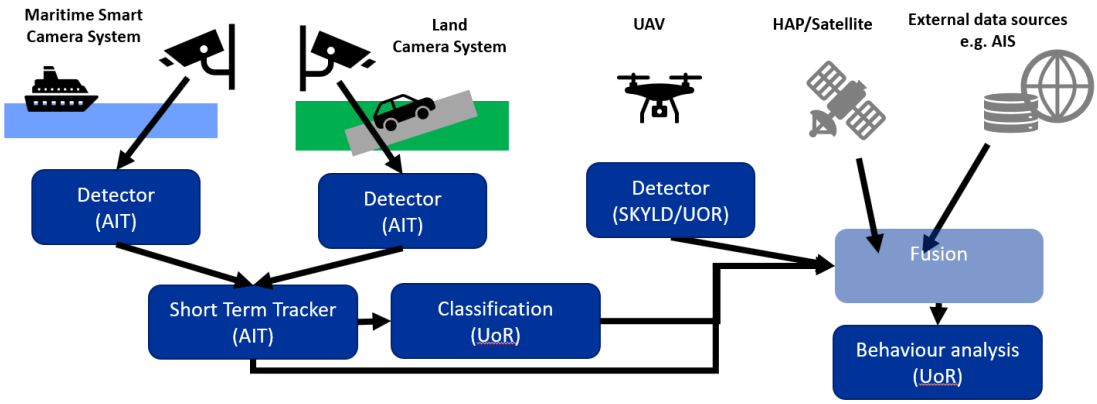
Coastal Ground and Low Altitude Sensing Systems

The EURMARS coastal and low-altitude sensing systems combine data from multiple camera-based platforms to enhance monitoring of maritime and coastal areas, as well as adjacent land zones. The setup integrates a Land & Sea smart camera system together with a dedicated maritime smart camera module, which employs multiple wavelengths beyond standard visual and thermal channels. These diverse sensors ensure reliable performance across a range of environmental and visibility conditions.

To complement fixed systems, two unmanned aerial vehicle (UAV) platforms were deployed, providing live video streams to the EURMARS platform. UAVs extend coverage to areas beyond the immediate coastline and support rapid verification of events detected by ground-based systems.



The video streams from these sensors are processed by advanced detection algorithms for maritime object identification. Tracking capabilities enable monitoring of detected objects within operational areas. Each detection is then passed through a classification module, which assigns detailed categories to the observed objects.

All collected information is integrated into the project's data fusion platform, which consolidates inputs from multiple sensors. The fused data supports behaviour analysis models capable of identifying unusual or suspicious patterns, thereby strengthening situational awareness for end users.

This integrated approach combines smart sensing, UAV support, and advanced analytics into a coherent system that significantly enhances detection, tracking, and behavioural understanding in coastal and maritime environments.

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High Altitude Sensing Systems

EURMARS integrates advanced sensors on high-altitude platforms, providing reliable, geo-referenced maritime detection based on change detection in marine environments. This innovative use of high-altitude platforms for maritime surveillance represents a novel contribution, offering persistent, wide-area coverage at reduced operational costs compared to traditional aerial surveillance assets.

Satellite-Based Systems

EURMARS incorporates space-based surveillance to strengthen maritime monitoring and support decision-making across national and European authorities. By combining both Synthetic Aperture Radar (SAR) and optical satellite imagery from sources such as Sentinel-1, Sentinel-2, Landsat-8 and 9, the system ensures wide-area coverage under all weather and lighting conditions. This provides a reliable system of situational awareness that complements ground, aerial, and high-altitude surveillance assets.

A dedicated satellite component was developed to detect vessels and oil spills over large maritime areas. It enables authorities to identify irregular activities such as trafficking, unregulated fishing, or environmental incidents, and supports crisis and emergency responders with timely intelligence. Automated image pre-processing steps including atmospheric correction, cloud removal, and georeferencing prepare the data for analysis. Advanced AI and machine learning models are then applied to both SAR and optical images to detect vessels, while an additional algorithm for oil spill detection was applied to the SAR data.

This component is designed to provide frequent monitoring with near-real-time analysis, operating day and night regardless of weather conditions. By offering scalable and cost-effective surveillance capabilities, it facilitates more efficient border control, maritime safety operations, and environmental protection.

The target users of this system include law enforcement agencies, coast guards, naval authorities, civil protection services, crisis management teams, and policymakers, as well as research institutions and technology providers working in the security and surveillance domain. Through integration into the EURMARS platform, satellite-based systems reinforce Europe's capacity to monitor its maritime borders and respond rapidly to evolving threats.

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Unmanned Aerial Vehicles (UAVs)

Within EURMARS, operate as a mobile, on-demand sensing layer, activated in response to abnormal events detected by other sensors. Their primary role is to support coastal monitoring, enabling the detection and tracking of maritime objects across extended operational areas. UAVs are particularly valuable in verifying and confirming abnormal events detected by other sensors, thereby strengthening the reliability of the overall surveillance system.

Equipped with advanced electro-optical and infrared (EO/IR) cameras, UAVs deliver high-resolution imagery both during the day and at night, ensuring continuous situational awareness even in low-visibility conditions. By generating geo-referenced detection events, they enable operators to precisely localize targets and assess situations in real time.

A key objective of the UAV component is to enhance operational decision-making. For example, UAVs can track vessels approaching designated areas and provide relevant intelligence to appropriate authorities. Their ability to patrol targeted sea areas, combined with real-time data processing, makes them a crucial asset for timely response in maritime border surveillance.

Integrated into the wider EURMARS platform, UAVs contribute to a multi-layered sensing approach, bridging the gap between coastal ground systems and high-altitude or satellite-based surveillance technologies.

Digital Interfaces and Middleware

EURMARS incorporates a Digital Integration and Interoperability Environment (DIIEI) to ensure connectivity with external data sources such as AIS and CISE, while enabling future integration with external EURMARS data consumers. The RCCS middleware manages sensor information through a centralized repository, abstracts underlying technologies, and guarantees security intelligence by logging all critical system interactions. These layers ensure interoperability, scalability, and secure system integration.

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Multimodal Data Fusion Platform (MDFP)

The Multimodal Data Fusion Platform (MDFP) is at the core of the EURMARS system, enabling the integration and interpretation of diverse sensor inputs into coherent, high-confidence situational awareness outputs. By consolidating detections and tracking information from coastal sensors, UAVs, high-altitude platforms, and satellites, MDFP transforms fragmented data streams into actionable intelligence for end-users.

At its foundation, the platform incorporates the Multimodal Fusion Architecture for Sensor Applications (MuFASA), which employs a real-time Bayesian inference system to establish spatio-temporal coincidences across sensor observations. This approach significantly improves detection confidence while reducing false alarms.

To further enhance operational value, a Fusion Tracking Module processes fused detections and generates reliable object tracks. Using the Kuhn-Munkres (Hungarian) algorithm in combination with Kalman filtering, the module provides consistent monitoring of moving vessels and vehicles, even under challenging conditions.

A key feature of MDFP is the Feedback Loop Module, which allows the system to interact dynamically with sensors. For example, it can request UAV deployment to verify satellite detections, adjust the orientation of coastal cameras, or trigger multispectral sensors when optical performance is compromised by weather or lighting. This adaptive behaviour ensures continuous optimisation of the surveillance network and maximises resource efficiency.

Finally, a dedicated Simulation Environment supports the development, testing, and evaluation of fusion and behaviour analysis modules. Users can design custom scenarios, simulate sensor configurations, and automatically annotate events of interest, such as vessel rendezvous or entry into restricted zones.

Through this combination of real-time fusion, adaptive feedback, and simulation capabilities, the MDFP delivers a robust and scalable framework for reliable detection, tracking, and analysis in maritime border surveillance.

Behaviour Analysis Module

The behavioural analysis module of EURMARS was developed to automatically detect and interpret events involving vessels, vehicles, and persons, thereby enhancing situational

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awareness in maritime surveillance. Its primary objective is to identify pre-defined behaviours of interest and provide semantic interpretations that are directly useful for end-users.

The system focuses on detecting anomalous maritime activities and vessel behaviour patterns that may indicate situations requiring authority attention. These behaviours often represent operationally significant events, including smuggling attempts, irregular migration, or suspicious coordination between vessels.

The detection process is based on a three-step algorithmic approach. First, tracklet calculation extracts points of interest from movement trajectories, identifying speed or direction changes. Second, zone learning uses clustering techniques to define activity zones based on these movement variations. Finally, semantic event detection translates the observed patterns into meaningful descriptions using a set of predefined rules.

This extended approach goes beyond earlier algorithms, which mainly focused on group formation and separation. In EURMARS, the scope was broadened to include additional event types such as vessels anchoring, approaching shorelines, or other complex maritime behaviours.

By moving from raw trajectory data to semantically rich descriptions of behaviour, this module enables authorities to more effectively recognise and respond to unusual or suspicious activities, contributing to timely decision-making and more secure maritime border management.

Decision Support System (DSS)

The EURMARS Decision Support System (DSS) provides actionable recommendations to authorities and end-users based on the assessed risk level, type of incident, and probability of successful mitigation. Rather than replacing user expertise, the DSS is designed to complement and enhance operational decision-making by embedding end-user knowledge at its core.

A key innovation of the DSS is the introduction of micro-tasks, which break down established Common Operational Procedures (COPs) into actionable steps. Each micro-task provides specific guidance on how to carry out an operational activity, making the DSS a practical companion during incident handling. End users contribute to this process by adding micro-tasks and rating their usefulness, enabling the system to refine and

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prioritise the most valuable tasks over time. This ensures that recommendations remain relevant, user-driven, and operationally grounded.

The DSS employs advanced AI techniques, including Large Language Model (LLM), to analyse and integrate micro-task feedback, transforming user inputs into coherent, adaptive recommendations. Through this continuous learning process, the DSS evolves to provide context-aware, targeted support for each operational step.

When a threat is detected, the DSS displays the relevant COPs along with associated micro-tasks. Users retain full flexibility to decide which actions to implement, and once the response is complete, they can provide feedback. This feedback loop enables ongoing refinement, ensuring that the DSS delivers meaningful and practical support tailored to real-world operational contexts.

By combining structured protocols, user expertise, and AI-driven adaptability, the DSS strengthens situational awareness and improves the efficiency and accuracy of maritime border surveillance operations.

Risk Assessment Tool (RAT)

The RAT integrates outputs from the fusion and behavior modules, DSS low-level events, and external geospatial datasets to deliver real-time threat identification, risk ranking, and predictive assessments. Compliant with the Common Integrated Risk Analysis Model (CIRAM), the RAT contextualizes surveillance events with environmental, temporal, and operational data to generate human-readable threat levels. This supports decision-makers in prioritizing responses and allocating resources effectively.

Collaborative Visualization and Analysis (C2VA)

EURMARS offers a GIS-based real-time web platform that enables interactive collaboration across agencies. C2VA integrates data from all sensing layers, the MDFP, DSS, and RAT, presenting them in an intuitive geospatial interface. This platform allows end users to jointly analyze events, share situational awareness, and coordinate responses, reinforcing EURMARS's vision of multi-authority cooperation in border security.

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Privacy, Ethical and AI related Issues and Outcomes

As part of the research process for the development of a suitable framework for analysing EURMARS' features, an extensive literature review was conducted of ethics, regulatory, social and privacy-related factors influencing BM, its regulatory framework, and previous security projects tackling similar issues, to ensure key learnings are integrated in new BM technology. The methodology included co-design participatory methods employed since the early start of the project's lifecycle, including workshops, dedicated consortium risk assessment meetings and partner technical surveys. To capture the intricacies of end-user requirements, the impacts of technology deployed as part of their operations, and challenges to comply with new legislation such as the AI Act, we organized a workshop with project partners, end-users, and opened the workshop to civil society representations, an followed up with a survey on technical development explainability components, aimed to bring at the forefront the role of explainability features and end-user understanding of how/why systems classify threats and recommend actions. To ensure alignment with EU standards and best practices, dedicated trainings were held on the AI Act & GDPR implications with project partners at early project stages. Additionally, EURMARS demonstration participants were trained on ethical principles driving the use of the platform, including risks and responsibilities that come with the human-in-the-loop approach.

The EURMARS project was governed by an Ethics-by-Design framework, involving placing ethics as a main consideration throughout all product development stages. Early project work included a Human Rights Impact Assessment/Fundamental Rights Impact Assessment (HRIA/FRIA), guided by the EU Charter of Fundamental Rights and the European Convention on Human Rights; and AI-related Risk Assessment (AIRA), guided by the AI-HLEG 'Assessment List for Trustworthy Artificial Intelligence (ALTAI)' and EC guidance on Ethics by Design. As a result of this research, we identified various risks that were integrated into an Ethics Risks Assessment Table (ERAT), a project dedicated tool designed to assess ethics-related risks, mitigation solutions, and support monitoring efforts throughout the project. For each risk, we recommend measures to prevent, minimise and mitigate any potential negative personal/social/environmental impacts

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during the research/development, deployment and post-deployment phase of the advanced surveillance platform proposed within the EURMARS project.

To support ethics monitoring efforts throughout the project, a dedicated Ethics Advisory Board reunited to discuss project progress on a quarterly basis. Final ethics advisory members' feedback revealed great satisfaction with the partners' cooperation and proactive approach on tackling data management and privacy risks arising from the nature of our work, and expressed enthusiasm on the EURMARS platform going forward.

Scientific Results

The EURMARS project produced a strong set of scientific contributions published in peer-reviewed journals, book chapters, and international conference proceedings. These outputs disseminate the project's results to the research community, practitioners and policy stakeholders.

Published Publications

EURMARS: An Advanced Surveillance Platform to Improve the European Multiauthority Border Security Efficiency and Cooperation

Mourkousis, G. et al. (2025). EURMARS: An Advanced Surveillance Platform to Improve the European Multiauthority Border Security Efficiency and Cooperation. In: Gkotsis, I., Kavallieros, D., Stoianov, N., Vrochidis, S., Diagourtas, D., Akhgar, B. (eds) Paradigms on Technology Development for Security Practitioners. Security Informatics and Law Enforcement. Springer, Cham. https://doi.org/10.1007/978-3-031-62083-6_31

Abstract: European maritime border management is a complex and multifaceted task. EURMARS innovates border surveillance in Europe by addressing the main challenges of irregular migration attempts, smuggling, trafficking, as well as management of search and rescue operations and oil spill observation and monitoring in parallel with the coordination and cooperation among different authorities and agencies at the national and EU levels. EURMARS implements and intends to validate a 24/7 surveillance platform with the following characteristics: (i) provision for the integration of existing and future data sources and services; (ii) utilisation and clustering of high-altitude technology,

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satellite imagery, UAVs, and ground-based sensors into a joint surveillance capability to provide continuous complementary data; (iii) innovative coupling of sensors data with data fusion, AI analytics, risk assessment, and alarming functionality; (iv) flexible interoperable surveillance platform with multiauthority cooperation capabilities and verified easy-to-integrate potential for next-generation platforms and systems; and (v) performance benchmark platform to ensure acceptability by all stakeholders, including extensive technical and user acceptance tests and ethical and legal impact assessments.

Requirements Reuse in Complex European Security Research Projects – A Border Management Perspective

Salmela, L., Laarni, J., Väätänen, A., Toivonen, S. (2024). Requirements Reuse in Complex European Security Research Projects – a Border Management Perspective. In: Tareq Ahram, Waldemar Karwowski, Dario Russo and Giuseppe Di Bucchianico (eds) Intelligent Human Systems Integration (IHSI 2024): Integrating People and Intelligent Systems. AHFE (2024) International Conference. AHFE Open Access, vol 119. AHFE International, USA.

http://doi.org/10.54941/ahfe1004521

Abstract: European civil security research most often builds upon a series of interlinked efforts and development work, extending vertically across different funding and work programmes and horizontally across various funding instruments. Requirements reuse may provide a means to benefit from advances made in previous projects and enhance consistency between related equipment and systems. Requirements reuse as part of requirements development may support human systems integration (HSI) by transmitting knowledge or simply repurposing well-defined HSI requirements into the design of new technologies. This paper examines the potential of requirements reuse in EU border management research especially addressing user requirements. We explore our findings from the perspective of HSI that merges the knowledge and skills of different areas of human and organizational factors. The results are based on requirements development processes from seven multiannual EU funded border management projects, in which the authors have conducted research. In our analysis, we identify many factors influencing requirements reuse across separate border management projects. Despite heterogenous practices of requirements development implemented in European projects, the created

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requirements knowledge base should be utilised in an effective manner. Requirements reuse has multiple benefits and it should be considered more carefully in future when planning new projects.

Participatory Approach for Specifying User Requirements for a Maritime Border Surveillance System

Salmela, L., Toivonen, S., Laarni, J., Keränen, J., Väätänen, A. (2024). Participatory approach for specifying user requirements for maritime border surveillance system. In: Tareq Ahram, Waldemar Karwowski, Darko Etinger and Tea Mijač (eds) Human Systems Engineering and Design (IHSED2024): Future Trends and Applications. AHFE (2024) International Conference. AHFE Open Access, vol -2. AHFE International, USA.

http://doi.org/10.54941/ahfe1005558

Abstract: Maritime safety and security in European waters constitute of organizationally multi-layered activities, also including cooperation, coordination and information exchange between numerous civilian and military authorities and European agencies. Risks and threats at sea are multifaceted with increasing complexity over time and managing them requires increased collaboration at various levels for achieving comprehensive situational awareness and operational efficiency. A multitasking platform integrating new sensing capabilities from coastal, low-altitude and high-altitude platforms with different external data sources and exploiting novel AI supported risk assessment and visualization capabilities may support national authorities in reaching these objectives. This paper reports a user requirements development process for such a system implementing participatory, iterative design approach. Security-critical development context may severely constrain requirements process in a multi-stakeholder environment. However, in-depth interaction between users and developers does ensure consistent, holistic, and unambiguous requirements process, thus increasing technology acceptance and project success.

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EURMARS: Use of Satellite Imagery as an Asset for Maritime Environment Rapid Tracking and Object Detection in Large Areas

Olympia Kourounioti, Christos Kontopoulos, Hong Wei, Ana Urbas, Tomaz Rodic, Hubert Fröhlich, James Ferryman, Vasiliki Charalampopoulou"EURMARS: Use of Satellite Imagery as an Asset for Maritime Environment Rapid Mapping and Object Detection in Large Areas"Information & Security: An International Journal,55no. 2(2024):149-164. https://doi.org/10.11610/isij.5524

Abstract: The increasing complexity of maritime risks and threats requires accurate and timely identification for environmental and human safety. Satellite observations enable comprehensive surveillance of large maritime areas, which is essential for detecting and responding to environmental changes and potential threats. The Horizon Europe project EURMARS aims to develop and validate a multi-purpose observation platform to enhance detection capabilities for various risks and threats. This paper introduces a novel Earth Observation (EO) algorithm based on Object-Based Image Analysis (OBIA), employing a You Only Look Once (YOLO) -v9 model to process data from open-access satellites (Sentinel-1, Sentinel-2, Landsat 8, 9) and video from the microsatellite NEMO-HD. Automatic Identification System (AIS) data are used to ensure comprehensive monitoring and validate the method's results. Satellite imagery with AIS data integration is a critical element of the vessel tracking methodology, significantly improving the accuracy and reliability of maritime surveillance. Real-life demonstrations have confirmed the method's effectiveness in enhancing maritime security and facilitating early detection and response to threats.

State-of-the-Art in Human-Centric Studies of AI-Enhanced Situational Awareness within the Security Domain

Salmela, L., Okkonen, J., Heikkiniemi, R. (2025). State-of-the-art in human-centric studies of AI-enhanced situational awareness within the security domain. In: Tareq Ahram, Waldemar Karwowski, Carlo Martino, Giuseppe Di Bucchianico and Vincenzo Maselli (eds) Intelligent Human Systems Integration (IHSI 2025): Integrating People and Intelligent Systems. AHFE (2025) International Conference. AHFE Open Access, vol 160. AHFE International, USA.

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http://doi.org/10.54941/ahfe1005808

Abstract: Advanced situational awareness and decision-making systems in the security domain heavily build upon versatile combinations of different artificial intelligence models, potentially including their earlier versions. Often, the broad variety of implemented algorithms results in complex system architectures which may challenge human comprehension of expert users. System performance is frequently evaluated by different technical metrics against various data sets, such as model accuracy, precision, and recall. However, without any consideration of human-autonomy teaming or human-system interaction, the possibilities of executing comprehensive system assessments are likely to remain limited. This systematic review examines the current state-of-the-art in human-centric studies on situational awareness systems applying machine learning or artificial intelligence as key technologies. Our findings are based on up to 40 studies that were identified in our literature searches. This paper outlines the transition in research on the domain and current trends. It also discusses the research gap on human-centric approach

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Building an Assurance Case for Assessing a Novel Maritime Border Surveillance System

Salmela, L., Keränen, J., Laarni, J., Toivonen, S., Väätänen, A. (2025). Building an assurance case for assessing novel maritime border surveillance system. In: Tareq Ahram, Waldemar Karwowski and Darko Etinger (eds) Human Systems Engineering and Design (IHSED2025): Future Trends and Applications. AHFE (2025) International Conference. AHFE Open Access, vol 198. AHFE International, USA.

http://doi.org/10.54941/ahfe1006797

Abstract: An assurance case is a documented body of evidence providing a convincing and valid argument that a system is adequately built for a given application in a given environment. It is a requirements-based approach, in which requirements provide a reference for the assessment of determined features of the target system. System adequacy is demonstrated by presenting evidence and by justifying why the evidence supports particular requirement-based claims. As follows, a systems assurance case is a conceptual procedure within which reasoning about system validity takes place. It is a

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hierarchical ordering of system-related data extending from an abstract understanding of system performance to a concrete proof of the validity system. In this paper, we discuss the development of an assurance case for a maritime border surveillance system which aims at enhancing the situational awareness of border authorities at external maritime borders of the European Union and third countries. This paper discusses the benefits of the assurance case in the context of applied civil security research, considering among others the suitability and comprehensiveness of the approach compared to other methods, such as checklists and compliance matrices. The strength of the approach in organizing information associated with complex systems is also addressed.

Pending and In-Progress Publications

In addition to the peer-reviewed publications completed during the lifetime of the project, several further papers and conference contributions are currently in progress, under review, or planned for publication shortly after the end of EURMARS. These forthcoming works extend the project's scientific output and reinforce its commitment to sustained dissemination and impact within the research and practitioner communities.

1. Semantic Behaviour Modelling for Threat Detection in Maritime Security Prepared by the University of Reading (UREAD).
2. An Ethics-by-Design Approach for AI in the Security Surveillance Domain. Trilateral Research (TRI) submitted an abstract to the Surveillance Studies Network (SSN) 2024 Conference.
3. A UAV-Based Detector for Maritime Surveillance. Authors: Romaios Bratskas, Dimitrios Papachristos, Petros Savvidis, Enea Qerama, George Dahrouje, George Leventakis, and Ioannis Sigalas. Presented at the FAIEMA 2024: 2nd International Conference on Frontiers of Artificial Intelligence, Ethics, and Multidisciplinary Applications, held in Athens, Greece (October 1–2, 2024).
4. Application of Context-Aware Microtasks and Feedback Loops to Enhance Decision Support During Execution of Operational Procedures in the Border Management Domain
5. A Methodological Framework for Vessel and Oil Spill Detection Leveraging Satellite Imagery and AIS Data. Springer CCIS
6. Enhancing Maritime Awareness with Multi-Sensor Satellite Remote Sensing Techniques. Authors: Kontopoulos C., Kourounioti O., and Charalampopoulou V.

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Abstract submitted to the 'Tenth International Conference on Remote Sensing and Geoinformation of Environment (RSCy2024)', 8–9 April 2024, Cyprus.

7. "Multi-Altitude, Multimodal Surveillance System for Maritime Threat Detection". Authors: Thanet Markchom, Olympia Kourounioti, Matteo Marturini, Romaios Bratskas, Jonathan Boyle, Lulu Chen, George Voskopoulos, Stephan Veigl, Andreas Opitz, Anastasios Gkamaris, Dimitris Papachristos, James Ferryman, Andreas Kriechbaum-Zabini, George Leventakis. Journal: IEEE Sensors Journal. It will be submitted by University of Reading (UREAD).

Impact and Exploitation

Exploitation in the context of EURMARS refers to the strategic use of the project's technological, procedural, and knowledge-based results to generate value across commercial, operational, policy, and research domains. It includes actions that facilitate the uptake, application, or further development of outcomes by consortium partners, end-users, or third parties in Europe and beyond.

The EURMARS exploitation strategy was designed to maximise impact by enabling integration of innovations into operational workflows, commercial products, policy frameworks, and future research initiatives. It reflects the diverse backgrounds and goals of the consortium, ranging from industrial and commercial exploitation to policy advocacy and institutional adoption. Exploitation has been approached as a dynamic, ongoing process, evolving in parallel with the technical progress of the project.

A key feature of this strategy is the distinction between individual and joint exploitation pathways. While each partner identifies specific exploitation priorities, the overall framework ensures consistency with the collective objectives of the consortium, with a focus on delivering societal and operational value in the field of border and maritime surveillance. Exploitation is thus seen as the bridge between research outcomes and real-world impact, whether in the form of market deployment, standardisation, policymaking, or capacity building.

The strategy also seeks to maximise long-term value for stakeholders by ensuring that EURMARS outputs are technically mature, operationally relevant, and positioned for sustainability. This includes identifying operational gaps addressed by the project,

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validating solutions in realistic conditions, and engaging market actors early to facilitate adoption.

The exploitation objectives of EURMARS are threefold. On the commercial side, the project seeks to strengthen the competitiveness of industrial partners by enabling them to integrate EURMARS innovations into their product portfolios. From a scientific perspective, the project contributes to the research community by providing validated methodologies, datasets, and algorithms. Finally, on the societal level, EURMARS aims to enhance maritime safety, security, and environmental protection through more efficient monitoring and decision-making.

Exploitation is a collaborative effort across the consortium. Each partner contributes to identifying innovations, potential markets, and operational needs, which are consolidated into a shared framework. This approach ensures that exploitation outputs reflect both the technical achievements of EURMARS and the evolving external environment. By combining technical progress with continuous stakeholder input, the exploitation strategy positions EURMARS results for meaningful, long-term impact in the European security landscape.

Standardisation Results

The standardization activities within the EURMARS project aimed to ensure that the technologies and methodologies developed are fully aligned with recognized European and international standards, enhancing their reliability, interoperability, and long-term sustainability. At the same time, the project aimed to contribute to the evolution of existing standards by transferring knowledge about the innovative technological aspects of EURMARS to the wider standardization community.

To achieve these objectives, the project partners actively participated in relevant working groups and standardisation bodies throughout the project. This participation enabled the consortium to ensure compliance with existing frameworks and to influence the development of future working items in the areas of security, resilience, and space applications.

In particular, EURMARS partners contributed to:

- CEN/TC 391/WG3 – Risk, Resilience, and Emergency/Crisis Management

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- ISO/TC 20/SC 14/WG8 – Downstream Space Services and Space-Based Applications
- ENISA Ad-Hoc Working Group on Security Operations Centres (SOCs)

Through these participants, EURMARS partners ensured that the technologies developed comply with established standards and that their results can be easily integrated into existing operational and regulatory frameworks. In addition, a compliance matrix was created to systematically document compliance with national, European, and international standards, while identifying potential gaps for future standardization work. As a result, EURMARS succeeded in making its results reliable, operational, and ready to serve as a basis for future standardization activities in maritime safety and border surveillance applications.

Future Outlook / Sustainability

The EURMARS project has laid the foundations for a new generation of integrated maritime surveillance solutions by combining high-altitude sensing, satellite-based monitoring, advanced data fusion, and AI-driven decision support within a flexible, interoperable platform. Beyond the project's lifecycle, the results are positioned for sustained impact through several pathways: integration into operational workflows of end-user authorities, incorporation into industrial partners' product portfolios, and uptake by the research community for further innovation. Open architecture and alignment with European frameworks such as CISE and EUROSUR ensure compatibility and long-term relevance, while the contributions to open datasets and standards strengthen the sustainability of results. Continued engagement with stakeholders, together with exploitation and clustering efforts, provides a strong basis for future collaboration, adoption, and further development of EURMARS technologies across Europe and beyond.

Conclusion and Legacy

The EURMARS project concluded in September 2025, marking the successful completion of a major European effort to advance integrated maritime and border surveillance capabilities. Through its combination of technical innovation, ethical foresight, and

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operational validation, the project demonstrated how multi-authority cooperation and cutting-edge sensing technologies can converge to deliver tangible impact for European security and resilience.

EURMARS leaves behind a strong legacy. Beyond the validated platform itself, the project established enduring partnerships among research institutions, industry actors, practitioners and EU agencies. The methodologies, frameworks and technological solutions developed within EURMARS are now available to inform future initiatives, ensuring continued relevance to the evolving needs of border and maritime management.

The project's results will support next-generation surveillance systems, contribute to policy development, and serve as a reference point for future Horizon Europe actions in the security domain. EURMARS has set a benchmark for how collaborative innovation, grounded in ethics and operational validation, can strengthen Europe's collective capacity to manage complex transnational challenges.

Disclaimer

The views expressed in this report are those of the EURMARS consortium and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions nor any person acting on their behalf may be held responsible for the use of the information contained herein.

Project Information

- **Project Website:** https://eurmars-project.eu/
- **LinkedIn:** https://www.linkedin.com/company/eurmars-horizoneu
- **X:** https://x.com/EURMARS_Project
- **Vimeo:** https://vimeo.com/eurmarsprojecteu

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