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*Article*

# Artificial Intelligence and its integration in Naval Operations

# La Inteligencia Artificial y su integración en las Operaciones Navales

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**Abstract:** A literature review was carried out with the objective of analyzing the impact of artificial intelligence (AI) in the improvement of surveillance and reconnaissance systems, with emphasis on the early detection of threats in coastal areas. For this purpose, the parameters of the systematic methodology were followed to identify, select and analyze the most relevant information on the integration of AI in naval operations, with a particular focus on surveillance and reconnaissance systems. The search for information was carried out in recognized academic and technical databases, both in the general field and in the defense sector. The main sources used included academic databases such as Scopus, Google Scholar, Semantic Scholar and JSTOR, 35 studies were selected that met the defined inclusion and exclusion requirements, for the period between 2020 - 2025. Common patterns and factors were found within the review, which were organized into 6 topics for further analysis, namely: fundamentals and advances of AI in naval operations. AI techniques applied in surveillance and reconnaissance. Integration of AI with existing surveillance technology. Early warning systems and threat prediction. Practical implementation in security and defense strategies. Ethical, legal and cybersecurity aspects. The relevant results of the review show that the use of advanced algorithms (deep learning, neural networks, etc.) significantly improves the detection and classification of threats in maritime environments, optimizing the accuracy and speed of operational decision making. Likewise, it is evident that AI-based predictive models allow detecting anomalies and foreseeing threats in coastal areas, facilitating proactive responses and improving operational safety, depending largely on the quality and availability of data.

**Keywords:** Artificial intelligence; Naval operations; Naval security; Coastal security; Technology.

**Resumen:** Se llevó a cabo una revisión bibliográfica con el objetivo de analizar el impacto de la inteligencia artificial (IA) en la mejora de los sistemas de vigilancia y reconocimiento, con énfasis en la detección temprana de amenazas en zonas costeras. Para ello, se siguieron los parámetros de la metodología sistemática que permitió identificar, seleccionar y analizar la información más relevante sobre la integración de la IA en las operaciones navales, con un enfoque particular en los sistemas de vigilancia y reconocimiento. La búsqueda de información se llevó a cabo en bases de datos académicas y técnicas reconocidas, tanto del ámbito general como del sector defensa. Las principales fuentes utilizadas incluyeron bases de datos académicas como Scopus, Google Scholar, Semantic Scholar y JSTOR, se seleccionaron 35 estudios que cumplieron con los requisitos de inclusión y exclusión definidos, para el periodo comprendido entre 2020 - 2025. Se encontró dentro de la revisión patrones y factores comunes, que fueron organizados en 6 tópicos para su posterior análisis, esto

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son: fundamentos y avances de la IA en las operaciones navales. Técnicas de IA aplicadas en la vigilancia y el reconocimiento. Integración de IA con tecnología de vigilancia existente. Sistemas de alerta temprana y predicción de amenazas. Implementación práctica en estrategias de seguridad y defensa. Aspectos éticos, legales y de ciberseguridad. Los resultados relevantes de la revisión permiten reconocer que el uso de algoritmos avanzados (deep learning, redes neuronales, etc.) mejora notablemente la detección y clasificación de amenazas en entornos marítimos, optimizando la precisión y la rapidez en la toma de decisiones operativas. Así mismo, se evidencia que los modelos predictivos basados en IA permiten detectar anomalías y prever amenazas en zonas costeras, facilitando respuestas proactivas y mejorando la seguridad operativa, dependiendo en gran medida de la calidad y disponibilidad de datos.

**Palabras clave:** Inteligencia artificial; Operaciones navales; Seguridad naval; Seguridad costera; Tecnología.

## 1. Introduction

Is it possible to identify the presence of threats in real-time through recognition without the presence of a human being? 25 years ago, a supercomputer defeated a chess champion, Russian Garry Kasparov, a historic milestone that, however, was just the beginning of a long journey for Artificial Intelligence (AI) (Heras 2023). AI is a technology that has been advancing rapidly worldwide, both in civilian and military fields, and its integration into naval operations is no exception. In the military sector, it is driven by the need for evolution, with the constant search for faster and more powerful weapons or technologies, which is precisely what AI offers (Sweet 2023). It positions itself as a key tool to improve operational effectiveness and real-time decision-making. This review article addresses the question: What are the applications of AI that can be used in current naval operations, and how do they improve operational effectiveness? To answer this question, the impact of AI on surveillance and reconnaissance systems is evaluated, with a particular focus on early threat detection in coastal areas.

As is well known, there are already powerful countries using AI in military activities, many of which are unknown and remain confidential due to their use in attack or defense. In this context, it is important to highlight that AI technologies applied to the military field pose a huge challenge for countries that do not have access to these new technologies. In a short time, a huge gap will open between different military systems, separating those countries with AI-based systems from those without them (Corchado 2022). The methodology employed in this review is based on a systematic analysis of recent scientific and technical literature, using specialized databases and reliable sources. It includes scientific articles, technical reports, and case studies published in the last five years to ensure the current and relevant information. The methodological approach combines a narrative review with a critical analysis of AI applications in naval operations, identifying trends, challenges, and future opportunities.

The main objective of this review is to analyze the impact of AI in improving surveillance and reconnaissance systems, with an emphasis on early threat detection in coastal areas. To do so, the most relevant AI applications in this field are analyzed, such as the use of machine learning algorithms for satellite image interpretation, the integration of facial recognition, and the optimization of sensor networks for real-time data collection. Furthermore, it discusses how these technologies contribute to decision-making, enabling a quicker and more accurate response to risk situations. In the words of the current president of Russia, "The future will belong to AI, and the first country to master it will be the governor of the world." – Vladimir Putin.

This article is structured as follows: Section 1 introduces the topic and provides background information on the integration of AI in naval operations. Section 2 outlines the contributions of the study, summarizing the main findings from the reviewed literature.

Section 3 presents the methodology used in this systematic review, detailing the criteria and process for selecting and analyzing relevant studies. Section 4 discusses the key findings and insights derived from the reviewed literature, emphasizing the impact of AI on surveillance, reconnaissance, and early threat detection. Section 5 presents the results of the review, highlighting the significant advancements AI has made in improving operational effectiveness in naval operations. Section 6 draws conclusions based on the study's findings, underscoring the importance of AI in transforming naval operational strategies. Section 7 provides directions for future work, focusing on advancements in AI integration, the development of hybrid models, and the need for improved regulatory frameworks. The article concludes with a list of references used throughout the review.

## 2. Contributions

The contributions of this study are focused on providing a comprehensive review of the integration of AI in naval operations, particularly in the areas of surveillance, reconnaissance, and early threat detection. The main contributions include:

1. **Systematic Review of AI Applications in Naval Operations:** This study synthesizes 35 relevant studies, published between 2020 and 2025, that investigate AI's impact on improving surveillance and reconnaissance systems in naval environments. The review highlights the technological advancements in AI, such as machine learning algorithms and deep learning models, that have significantly enhanced the detection and classification of maritime threats.
2. **Identification of Key AI Techniques and Their Practical Applications:** The study provides an in-depth examination of AI techniques, including deep learning, convolutional neural networks (CNN), and machine learning models, that have been applied to object recognition, anomaly detection, and real-time maritime data analysis. This research contributes to the understanding of how these AI methods increase the efficiency and accuracy of surveillance systems.
3. **Integration of AI with Existing Surveillance Technologies:** One of the study's contributions is identifying how AI can be integrated with traditional surveillance technologies like radars, satellites, and UAVs. The synergy between AI and existing technologies is crucial for improving detection resolution, optimizing resource management, and enabling more effective decision-making in maritime operations.
4. **Development of Early Warning Systems and Predictive Models:** Another key contribution is the exploration of AI-based predictive models for early threat detection. The study demonstrates how AI can be leveraged to predict anomalies and vulnerabilities in coastal areas, thus enabling proactive responses and enhancing operational security.
5. **Technological and Operational Challenges:** The review also identifies challenges in the operational implementation of AI, such as the dependency on large datasets, the need for real-time data quality, and the adaptation to dynamic operational environments. These findings underscore the importance of continued research into improving AI algorithms and addressing gaps in data collection and management.
6. **Ethical, Legal, and Cybersecurity Considerations:** The study also emphasizes the growing importance of ethical, legal, and cybersecurity issues in the implementation of AI systems within naval operations. It highlights the need for regulatory frameworks to ensure the responsible and secure use of AI technologies, as well as addressing concerns related to privacy and data protection.
7. **Practical Implications for National Security:** The research proposes practical applications of AI in naval defense, such as the use of AI-driven systems for coastal surveillance, route optimization, and strategic decision-making in naval operations. Notably, the study discusses the potential of technologies like the Black Hornet nanodrone and laser weapon systems integrated with AI, which can enhance the operational capacity of naval forces and improve national security.

## 3. Methodology

To conduct this review, a systematic methodology was followed that allowed for the identification, selection, and analysis of the most relevant information on the integration of AI in naval operations, with a particular focus on surveillance and reconnaissance systems. The following outlines the steps and criteria used in the research process.

The information search was carried out in recognized academic and technical databases, both general and defense-related. The main sources used included academic databases such as Scopus, Google Scholar, Semantic Scholar, and JSTOR. Additionally, defense-specific databases such as the Defense Technical Information Center (DTIC) and the Naval Research Laboratory (NRL) were utilized. These sources were selected for their relevance, reliability, and thematic coverage, ensuring an approach that encompassed both technological and operational aspects.

Clear criteria were established for selecting the studies and documents included in the review:

**Inclusion Criteria:**

- Scientific articles, technical reports, and case studies published between 2020 and 2025.
- Documents addressing AI applications in naval operations, particularly in surveillance, reconnaissance, and early threat detection.
- Studies providing empirical evidence or theoretical analysis on the operational effectiveness of AI.
- Publications in English and Spanish.

**Exclusion Criteria:**

- Documents not directly related to naval operations or AI.
- Studies lacking methodological rigor or not supported by reliable sources.
- Publications prior to 2020, except those deemed essential for historical context.
- Articles not available in full text.

**Search Strategies:**

The search was conducted using a combination of keywords to optimize the results. The keywords included terms such as: 'artificial intelligence', 'naval operations', 'maritime surveillance', 'early threat detection', 'autonomous systems', 'machine learning', 'Deep learning'. The keywords were combined using Boolean operators:

- **AND:** To combine terms and narrow the search (e.g., "artificial intelligence" AND "naval operations").
- **OR:** To include synonyms or related terms (e.g., "maritime surveillance" OR "coastal monitoring").
- **NOT:** To exclude irrelevant topics (e.g., "artificial intelligence" NOT "medicine").

Additionally, filters were applied for temporal range (2020-2025) and language (English and Spanish) to ensure the timeliness and accessibility of the information.

The initial search yielded a total of 2,430 documents. After removing duplicates and applying the inclusion and exclusion criteria, 35 studies were selected for detailed review. These documents were analyzed based on their thematic relevance, methodological quality, and contribution to the research objective.

The analysis focused on identifying AI applications in naval operations, evaluating their impact on operational effectiveness, and highlighting the associated challenges and opportunities. The literature search was completed on February 11, 2025, ensuring that the review included the most recent and relevant studies on the topic.

## 4. Discussion

Once the suggested review was developed, a series of contributions from academia on the research topic were found, and to better manage them, they were grouped into a series of subtopics that help establish the impact of AI in naval operations, specifically in the areas of reconnaissance and surveillance.

Initially, the identification of the foundations and advances of AI in naval operations is presented. In this regard, it is important to consider technological evolution. A series of studies highlight the transition from traditional methods to AI-based approaches (Masria and Abouelsaad 2025). Both the theoretical foundations of AI applied to maritime environments and the evolution of its algorithms to improve pattern recognition and the identification of anomalous behaviors are discussed (las Heras 2023).

There is evidence of a trend in improvements in operational efficiency and the ability to process large volumes of data (Xataka 2025). However, the need to overcome challenges such as environmental variability and the lack of labeled data in certain maritime scenarios is also noted. All of this points to process optimization, although gaps remain in achieving proper adaptation to real and complex conditions. The development of hybrid models and multimodal data may help bridge these gaps (Matiz-Rojas and Fernández-Camargo 2023).

These studies agree that AI's ability to integrate and analyze data from multiple sources (satellite images, remote sensors, historical records) is fundamental to improving surveillance and security in coastal areas. However, they emphasize that the success of these applications largely depends on the quality and quantity of available data, which implies an investment in information collection and management infrastructures. This is why many of the leading powerhouse countries invest large amounts in advancing these technologies (Figure 1).

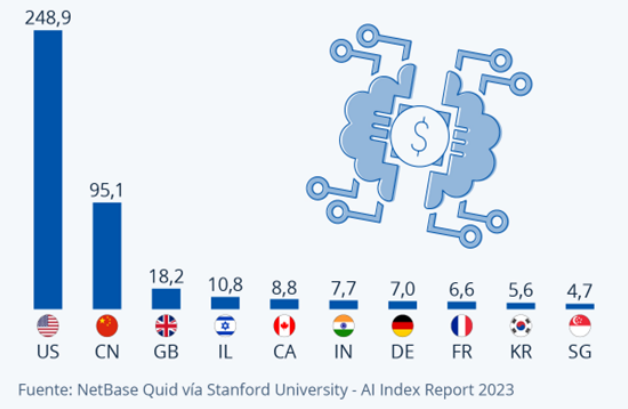


**Figure 1.** Countries with the largest private investment in artificial intelligence from 2013 to 2022 (USD).

**Note:** Chart showing the countries with the highest private investment in AI during the period from 2013 to 2022, expressed in billions of U.S. dollars (USD). The data reflects the growth and geographical distribution of resources allocated to the development of AI technologies globally. Taken from (Statista 2025).

The reviewed studies emphasize the transformative potential of AI in maritime surveillance and security, while highlighting the importance of addressing the challenges inherent to its operational implementation. While modern algorithms can outperform traditional methods in accuracy, challenges such as managing false results, adapting to changing conditions, and the need for continuous model training still persist. The theoretical review suggests that the future of AI in naval operations will be marked by the development of hybrid models that combine different machine learning techniques to achieve greater robustness and adaptability (UNESCO 2023).

Another relevant topic in the review pertains to AI techniques applied to surveillance and recognition. Fourteen contributions were found in the literature reviewed, providing a general overview of the techniques that have been developed and their usefulness. Deep learning, convolutional neural networks (CNN), and other machine learning models for object recognition, anomaly detection, and real-time maritime data analysis are part of the offering (Reis et al. 2024). Among the issues addressed are the more precise identification

of illegal vessels, the development of illicit activities, and atypical behaviors that may occur. This points to an increase in the effectiveness of surveillance and control.

The use of advanced algorithms has enhanced the ability of systems to process satellite images, sensor data, and real-time videos. However, the effectiveness of these methods largely depends on the quality and quantity of available data, as well as the capacity to adapt to different operational environments. It is recommended to continue investigating the optimization of these models and their validation in real-world scenarios (Green 2025).

On the other hand, a high effectiveness of AI was found when integrated with existing surveillance technologies such as radars, satellites, remote sensors, and autonomous vehicles (UAVs), etc. At this point, the combination of data from different mechanisms helps to define a more complete and detailed image of the situation in real time, reducing the margin of error in decision-making (Solutions 2023)).

In general, the contributions studied reinforce the premise that the integration of AI with existing technologies not only improves the resolution and speed of detection but also optimizes resource management. The synergy between various technological platforms is crucial for developing robust surveillance systems, although standardized protocols are needed to ensure interoperability between disparate systems.

The review also highlighted the importance of early warning systems and threat prediction. Seven contributions found show how AI-based models allow for predicting vulnerabilities and special behaviors in real time, facilitating early threat detection, from illicit activities to adverse environmental events (Fannassi et al. 2023). The application of big data techniques and predictive analytics contributes to the development of early warning systems that can prevent critical incidents in coastal areas (Matiz-Rojas and Fernández-Camargo 2023) (Figure 2).


**Figure 2.** Explorer, a Saildrone (autonomous sailboat) that operates without a crew.
**Note:** Explorer a Saildrone (unmanned autonomous sailboat), during tests conducted in the Persian Gulf on June 26, 2022. This vehicle is part of the United States Navy's technological push to strengthen its strategic presence in the face of growing global competition, particularly against China (Post 2022; Sharp 2022).

Another approach found in the reviewed contributions relates to the use and practical applications in naval forces, where AI is used to optimize routes, improve incident response, and increase security at ports and maritime borders (Dimitrov 2024). A positive impact on the efficiency of naval operations is observed, thanks to the integration of AI systems that facilitate real-time decision-making.

The practical application of AI in coastal defense and security demonstrates improvements in operability and response capability to threats. However, the transition from experimental models to robust operational systems requires overcoming technical and logistical challenges, as well as adapting existing military protocols. Evidence suggests that

the success of these implementations depends both on technological innovation and on the training and updating of operatives (Thorne 2020).

A final approach found is characterized by the treatment of ethical, legal, and cybersecurity aspects. A growing trend is evident in addressing challenges such as the use of AI in terms of privacy, data protection, and legal compliance. In terms of national security, the issue becomes more delicate, making this topic one of great importance for the naval context.

In general, it was identified that the evolution of AI has allowed the development of models and algorithms that, when applied to the maritime environment, open new possibilities for coastal surveillance and security. Studies like "Artificial intelligence applications in coastal and marine environments" and "The challenge of artificial intelligence for sea security" emphasize the transition from traditional methods to AI-based approaches, highlighting both technological advancements and inherent challenges (Figure 3).

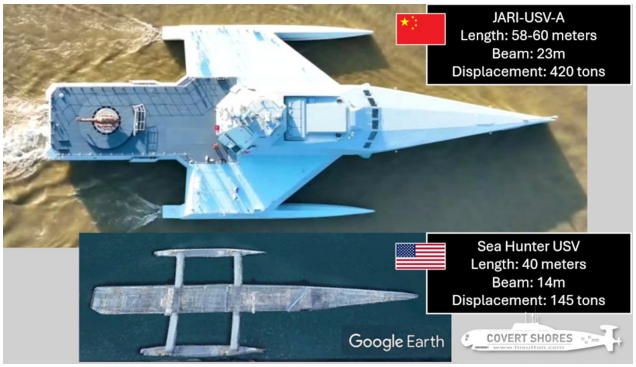


**Figure 3.** Approximate size comparison with the US Navy's USV Sea Hunter.
**Note:** The image shows an approximate comparison between the USV Sea Hunter (USA) and the JARI-USV-A (China) (Sutton 2022).

These findings indicate that the theoretical foundation and technological advances in AI are enabling the resolution of complex problems in the naval domain. Following the research question, it is demonstrated that fundamental AI applications (such as image processing, data analysis, and pattern recognition) lay the groundwork for developing systems that enhance operational effectiveness in maritime surveillance and security.

Other reviewed studies, such as those by Masria and Abouelsaad (2025), agree that technological evolution is a key factor, though they emphasize the need to adapt these advances to real operational environments. There is a convergence in the literature regarding the importance of data quality and model scalability, aspects that are similarly addressed across multiple articles.

As theoretical implications, emphasis is placed on the need to develop hybrid models and integrate various AI techniques to optimize decision-making in complex contexts. From a practical perspective, technological advancements can translate into significant improvements in surveillance and the ability to respond to threats, although implementation requires adaptation to environmental and operational variables. An important limitation is the challenge of managing large volumes of data, adapting to dynamic conditions, and the need for robust infrastructures.

The use of deep learning algorithms, convolutional neural networks, and machine learning models for image processing, anomaly detection, and pattern recognition in maritime environments is highlighted. Articles such as "Automatized marine vessel monitoring from Sentinel-1 Data Using CNN" and "Deep Learning Models for Real-Time Threat Detection in Coastal Waters" demonstrate the effectiveness of these methods.

The findings show that the application of advanced AI techniques significantly improves accuracy in identifying suspicious activities and object recognition, which is crucial for surveillance and reconnaissance in naval operations. This answers the research ques-

tion by demonstrating that, by improving detection accuracy, AI enhances operational effectiveness and security.

Coherence is observed in the literature, as studies, including Dimitrov (2024), highlight the ability of these techniques to process real-time data and reduce errors in detection. The comparison indicates that, although there are differences in the implementation and performance of algorithms, the consensus is that these techniques form the core of AI applications in the naval domain.

Regarding theoretical implications, there is an opportunity to integrate supervised and unsupervised learning models to improve the robustness of systems. The implementation of these models can also translate into smarter and more proactive surveillance systems, optimizing resources and reducing response times. The challenges include dependence on large volumes of labeled data, variability in data quality, and the need to validate models in real-world scenarios.

The importance of merging AI with traditional surveillance technologies, such as radars, sensors, satellites, and UAVs, was identified. Studies such as "Leveraging AI/ML for Enhanced Maritime Domain Awareness" and "AI-enhanced Satellite Imaging for Coastal Surveillance" demonstrate the benefits of this integration.

This leads to the premise that combining technologies allows for leveraging information from various sources, improving the ability to detect and respond to threats in real time. In relation to the research question, technological integration translates into greater operational effectiveness, as it allows for a more complete and accurate view of the maritime environment.

On the other hand, the literature shows consistency in the importance of interoperability between systems; several studies highlight that the fusion of data from different sensors increases reliability and reduces uncertainty in detection. The comparison shows that, although implementation varies, the consensus is that the synergy between AI and traditional technologies is an essential component in modernizing naval surveillance (Queirolo Pellerano 2019).

One theoretical implication points to the need to develop data fusion frameworks and communication protocols between heterogeneous systems (Yu 2024). Integration facilitates a more coordinated and efficient response, which can lead to a reduction in response times to incidents. Barriers include compatibility issues, high implementation costs, and the need for continuous updates to technological infrastructure.

Studies were also identified that point to the use of predictive models and real-time analytics techniques for early detection of threats and vulnerabilities in coastal areas. Examples such as "AI-Based Anomaly Detection in Maritime Traffic" and "Predictive Analytics for Coastal Security Using AI" demonstrate the ability to anticipate critical situations.

The findings indicate that the application of AI-based early warning systems allows for the identification of anomalous behaviors and the prediction of potential threats, facilitating preventive interventions. This answers the research question by showing that prediction and prevention are key applications of AI, improving operational effectiveness by anticipating incidents.

The review shows that various studies have obtained promising results in reducing false results and improving predictive accuracy. There is a consensus that the integration of big data and advanced detection algorithms is fundamental for establishing robust early warning systems (Tiwari et al. 2021).

A theoretical implication identified is the need to improve predictive models by incorporating contextual variables and continuous learning. Notable restrictions include dependence on the quality and availability of real-time data, as well as the possibility of false results that could generate unnecessary alarms.

On the other hand, practical applications of AI in naval operations were found, such as route optimization, maritime traffic prediction, and improvement in strategic decision-making. Studies such as "Smart Ports and AI-Based Security Measures" and "Maritime

Traffic Prediction using AI Algorithms" illustrate real use cases and the integration of AI in operational environments.

The findings indicate that the incorporation of AI in the daily operations of naval forces and ports not only improves security but also optimizes resources and processes, increasing effectiveness in responding to threats. In the context of the research, it is demonstrated that the practical application of AI is crucial for transforming security and defense strategies in the maritime domain.

The reviewed literature shows consistent results regarding the improvement of operational efficiency (Intelligence 2022), although some studies highlight challenges in the integration and scalability of solutions. It is observed that, while certain case studies report success in implementation, others indicate the need for operational adjustments to adapt to dynamic contexts.

The findings support the formulation of theoretical models (theoretical implication) that explain the relationship between intelligent automation and improved operational decision-making. In practice, this leads to the adoption of AI-based solutions, which could translate into safer and more efficient naval operations, optimizing resource allocation and improving real-time coordination. Challenges such as resistance to change, the need for specialized training, and the adaptation of pre-existing infrastructures to new technologies are highlighted.

In terms of ethical, legal, and cybersecurity aspects, the studies emphasize the importance of addressing ethical, legal, and cybersecurity issues in the implementation of AI systems in naval operations. Articles such as "Enhancing Port and Maritime Cybersecurity Through AI" and "Legal and Ethical Challenges of AI in Naval Operations" highlight the need for regulatory frameworks and risk mitigation strategies.

These findings indicate that, although AI offers significant operational advantages, its adoption in the naval domain must be accompanied by policies that ensure ethical, safe, and legally compliant use. Regarding the research question, it is evident that the development of intelligent systems must be balanced with safeguards that protect both the integrity of operations and the rights and safety of users.

The literature shows a consensus on the need to integrate cybersecurity measures and establish specific regulations for the use of AI in sensitive contexts. Some studies emphasize the risks associated with the vulnerability of these systems, while others propose integrated solutions combining advanced technology and robust regulations (Yu 2024).

From a theoretical perspective, the results call for the development of theoretical frameworks that integrate technological aspects with ethical and legal considerations, contributing to the creation of evidence-based policies. The implementation of AI systems in naval operations should be accompanied by cybersecurity strategies and updates to legal regulations, ensuring responsible and secure deployment.

Gaps in current legislation and challenges in implementing unified protocols are identified, which may limit widespread adoption and interoperability of solutions (Thorne 2020).

At this point, it is pertinent for the research to list successful cases of AI use in naval operations worldwide:

- USV Sea Hunter (USA). (Navy 2022)
- Laser weapons against drones. (News 2025)
- Chinese unmanned vessel JARI-USV-A. (Xataka 2024)
- Mini reconnaissance drone with FLIR system. (Systems 2025)
- Explorer - Unmanned Saildrone. (Times 2022)
- Unmanned marine drone. (Debate 2023)
- DARPA Submarine Drone Project. (Infobae 2024)

All of these cases are subjects of study, and while they have already shown efficient and promising results for operations, it is important to note that each one has particular characteristics. Based on these, adjustments are being made to achieve the required productivity.

## 5. Results

The review of the 35 articles presents a promising outlook on the application of AI in naval operations. Each of the topics covered contributes integrally to answering the research question, highlighting both technological advancements and the ongoing challenges in this field. In summary, the findings indicate that AI has far-reaching applications, ranging from detection and recognition of threats to the integration of advanced technologies and predictive systems that significantly improve operational effectiveness in maritime surveillance and defense.

The results reveal that AI is fundamental in transforming traditional operational processes. Through the use of advanced algorithms and machine learning, there has been an optimization in real-time decision-making, allowing for quicker and more accurate responses to risk situations. This progress has led to substantial improvements in the safety and efficiency of naval operations, facilitating the identification and classification of threats on a large scale, such as unauthorized vessels, illicit activities, or adverse conditions at sea.

Additionally, the review shows that the integration of AI with traditional technologies, such as radars, satellites, and autonomous vehicles (UAVs), has enhanced detection resolution and speed, reducing the margin of error in decision-making. This not only improves monitoring capabilities but also optimizes resource management, enabling naval forces to operate more efficiently and with reduced human and material resource use.

The application of predictive models based on AI has emerged as a crucial tool for predicting threats and early identification of anomalies, such as suspicious maritime traffic patterns or sudden changes in coastal environments. This has facilitated the implementation of early warning systems, enabling prevention of critical incidents and planning of proactive responses, thereby improving operational security in vulnerable coastal areas.

Despite these advancements, the studies also confirm that the quality and quantity of available data remain determining factors for the success of AI applications. Many of the reviewed studies emphasize that the lack of labeled data, variable environmental conditions, and the diversity in operational settings are persistent challenges that limit the effectiveness of AI systems in real-world scenarios. This highlights the need for significant investment in infrastructure for data collection and management, as well as improving the quality of the data.

Regarding theoretical and practical implications, the review shows that there is general consensus on the potential of AI, but its current limitations are also recognized, such as the management of large data volumes, the adaptability to changing conditions, and the need for continuous model training. The results suggest that overcoming these challenges will require the development of hybrid models that combine various techniques of supervised and unsupervised learning to enhance the robustness and adaptability of the systems.

The review also highlights that, while AI has enormous potential to improve naval operations, there is a need to continue with interdisciplinary research, focusing on the integration of new technologies and the development of robust regulatory frameworks to ensure the ethical and safe implementation of AI. This approach will contribute to solving current issues related to resistance to change and the lack of standardized protocols, which limit system interoperability.

## 6. Conclusions

Once the review of the 35 articles was completed, the task of identifying patterns in the results they had yielded was carried out, organizing them into topics that could be found in common. This led to the following questions: foundations and advancements of AI in naval operations; AI techniques applied in surveillance and reconnaissance; integration of AI with existing surveillance technology; early warning systems and threat prediction; practical implementation in security and defense strategies; ethical, legal, and cybersecurity aspects.

Each of these topics contributes to the study, showing the real state of AI in naval operations. The evolution of AI has laid the theoretical and technological foundations

for transforming naval operations, opening the door to more sophisticated surveillance systems, although challenges in adapting to real conditions still persist.

The use of advanced algorithms (deep learning, neural networks, etc.) also significantly improves the detection and classification of threats in maritime environments, optimizing accuracy and speed in operational decision-making. It is important to note that the fusion of AI with traditional technologies such as radars, satellites, and UAVs enhances surveillance by integrating multiple data sources in real time, although it requires overcoming challenges in interoperability and technological updates.

On the other hand, AI-based predictive models enable the detection of anomalies and the prediction of threats in coastal areas, facilitating proactive responses and improving operational security, largely depending on the quality and availability of data. Consequently, the direct application of AI in route optimization, maritime traffic prediction, and strategic decision-making demonstrates improvements in operational efficiency and security, although its full integration still faces operational and adaptation barriers.

Making a more specific landing in consideration of technologies that could be efficient for national operations, it is important to add that the implementation of the Black Hornet system in the Colombian Navy would represent a significant advancement in naval surveillance, reconnaissance, and maritime security operations. This exploration nanodrone, developed by Teledyne FLIR, is a key tool for improving terrain analysis in maritime and coastal environments, allowing naval units to gather real-time intelligence without exposing personnel to unnecessary risks.

Its compact size, silent flight capability, and live video transmission make it ideal for maritime interdiction operations, patrolling hard-to-reach areas, and supporting special forces units in boardings and amphibious reconnaissance missions. Additionally, the Black Hornet can be integrated with other AI systems for automated image processing and analysis, facilitating threat identification and decision-making in operations against drug trafficking, piracy, and other illicit activities in the Caribbean Sea and the Pacific Ocean. With this technology, the Colombian Navy strengthens its operational capacity and its adaptation to modern warfare based on autonomous systems and real-time data analysis.

Along the same lines, it is also relevant to consider the implementation of laser weapon systems with AI in the Colombian Navy, which represents a key advancement in defense against drones and unmanned aerial threats. Inspired by technology used by the U.S. Navy, this innovation enables faster and more accurate neutralization of hostile targets, optimizing security in naval operations.

These systems can detect, track, and eliminate reconnaissance or attack drones, protecting naval bases, surface units, and strategic maritime zones in Colombian territory. In a scenario where Organized Armed Groups (GAOs) and drug trafficking networks are seeking to modernize their tactics with drones for espionage or attacks, the integration of laser weapons with AI would provide a crucial advantage in protecting ships, maritime and riverine lines. Its implementation would enhance security in Colombia's rivers, where these vessels play a key role in the fight against drug trafficking, illegal mining, and armed groups. With this technology, the Colombian Navy would consolidate the development of an intelligent, modern naval and river defense system, aligned with new maritime and territorial security trends.

All of the above leads to a final point: the adoption of AI in the naval domain presents critical challenges in terms of ethics, legality, and cybersecurity, highlighting the need to develop regulatory frameworks and robust strategies to ensure responsible and safe use of the technology.

The development of this review exercise allows for a synthesized presentation of the state of AI regarding its usefulness in naval operations, with a particular focus on the utility of AI-based technology for recognition within naval prevention and security. Through a systematic reading, it provides insight into the technologies, their usefulness, and the challenges that arise as we enter the AI era, maximizing its benefits to optimize the performance of naval operations.

## 7. Future works

While this study has contributed to the understanding of the integration of AI in naval operations, there are several areas that warrant further exploration. Future research should focus on enhancing the robustness and scalability of AI models used in naval environments. Specifically, the development of hybrid models that combine both supervised and unsupervised learning techniques can offer improved adaptability to dynamic maritime conditions and more accurate predictions in real-time scenarios. Additionally, more work is needed to explore the integration of multi-modal data (e.g., satellite images, sensor data, historical records) to improve the reliability and precision of AI systems in coastal surveillance and reconnaissance.

Another promising avenue for future research is the development of standardized protocols for interoperability between AI-driven systems and traditional surveillance technologies like radars, UAVs, and satellite networks. Addressing these integration challenges will be critical in ensuring that disparate systems can work together seamlessly, reducing the margin for error and improving operational effectiveness. Furthermore, the ethical, legal, and cybersecurity concerns associated with the deployment of AI in sensitive military operations should be thoroughly examined. Researchers must work towards creating comprehensive regulatory frameworks that balance technological advancements with responsible and secure usage, safeguarding both national security and individual rights. Exploring these areas will be crucial in shaping the future of AI in naval operations, ensuring it is both effective and ethically implemented.

**Author Contributions:** The authors' contributions to this work are detailed in Table 1.

**Table 1.** Author contributions.

| Contribution | Torres. O | Meneses. G | Vélez. J |
|---|---|---|---|
| Conceptualization/Methodology | X | | |
| Software/Visualization | | X | |
| Validation/Formal analysis | | X | |
| Investigation/Resources | X | | |
| Data curation | | | X |
| Writing - original draft | | X | |
| Writing - review / Editing | | | X |
| Supervision/Project administration | | | X |
| Funding acquisition | X | | |

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**Informed Consent Statement:** This study is limited to the use of technological resources, so no human personnel or animals are involved.

**Conflicts of Interest:** Under the authorship of this research, it is declared that there is no conflict of interest with the present research.

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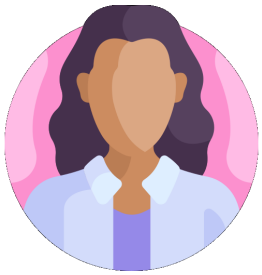

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