https://research.adra.ac.id /index.php/jssut/
P - ISSN: 3026-5959
E - ISSN: 3026-605X

Strengthening Underwater Security in ALKI II: Integrating Technology-Based Maritime Control Capabilities from a National Defense Perspective

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ABSTRACT

Background. The expansion of subsea infrastructure in ALKI II introduces complex security threats, demanding a strong synergy between advanced technology and institutional capabilities to maintain maritime domain awareness.
Purpose. This study investigates how technology-based control capabilities support underwater security and identifies the key organizational factors that determine their success from a defense perspective.
Method. Employing a qualitative case study design, data were gathered through semi-structured interviews with 30 key stakeholders, document analysis, and field observations, then analyzed using thematic coding and exploratory inferential analysis.
Results. Technology-driven capabilities significantly boosted situational awareness and institutional decision-making. High technological readiness strongly correlated with overall security effectiveness ($r = 0.74$, $p < 0.001$), with organizational readiness and staff competence serving as critical supporting drivers.
Conclusion. Technology alone is insufficient; sustainable underwater defense requires combining high-tech systems with skilled personnel, interoperable networks, sound governance, and cohesive interagency coordination.

KEYWORDS

ALKI II; Maritime Control; National Defense; Underwater Security; Technology Integration

Citation: Arifin, N. Y., Siagian, G. F. J., & Supriadi, Supriadi. (2026). Strengthening Underwater Security in ALKI II: Integrating Technology-Based Maritime Control Capabilities from a National Defense Perspective. *Journal of Social Science Utilizing Technology*, *4*(4), 241–258.
https://doi.org/10.70177/jssut.v4i4.4419

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Received: February 8, 2026
Accepted: July 11, 2026
Published: August 31, 2026

INTRODUCTION

Indonesia possesses a strategically important maritime position because its territory connects the Indian and Pacific Oceans and serves as a major component of global maritime connectivity (Elkhider & Imran, 2026a). The Indonesian Archipelagic Sea Lanes (ALKI) provide designated routes for international navigation through Indonesian waters while simultaneously intersecting with national interests in sovereignty, maritime security, economic activity, environmental protection, and defense (Wan & Li, 2026). ALKI II is particularly significant because it connects the Makassar Strait with the Flores Sea and surrounding maritime areas that support substantial commercial and strategic activity (Wei dkk., 2026). The intensity and diversity of maritime activities within these

waters create a complex security environment requiring continuous institutional awareness and effective within these waters create a complex security environment requiring continuous institutional awareness and effective maritime governance.

Underwater security has become an increasingly important dimension of contemporary maritime security because critical activities and potential risks are not always visible from the sea surface (Xu dkk., 2026). Subsea communication cables, pipelines, maritime infrastructure, underwater environmental resources, and submerged objects represent strategic assets or potential vulnerabilities that require appropriate monitoring (Mai dkk., 2025). Developments in autonomous systems, underwater sensors, satellite-supported maritime awareness, acoustic technologies, and integrated information systems have expanded the possibilities for detecting and assessing underwater conditions (Chu dkk., 2024). The emergence of these technologies provides opportunities to strengthen maritime control capabilities while also creating new requirements for institutional coordination, data management, personnel competence, and technological interoperability.

The concept of maritime security has consequently evolved beyond conventional surface surveillance toward multidimensional maritime domain awareness that includes surface, air, coastal, and underwater environments (Papandroulakis, 2026). Technology-based maritime control can contribute to this transformation by integrating information from multiple sources into a more comprehensive picture of maritime conditions (Elkhider & Imran, 2026b). A national defense perspective requires such technological capabilities to be considered within a broader framework of sovereignty, resilience, institutional preparedness, and lawful maritime governance (Gan dkk., 2025). Strengthening underwater security in ALKI II therefore requires an integrated approach that connects technological innovation with organizational capacity, regulatory frameworks, and national defense interests.

The underwater dimension of ALKI II presents distinctive challenges because activities and objects beneath the surface are inherently more difficult to observe than conventional surface activities (Jiang & Yang, 2026). Geographic complexity, oceanographic variability, water depth, acoustic conditions, and the extensive area requiring monitoring can limit the effectiveness of conventional maritime surveillance systems . Critical underwater infrastructure may also extend beyond the practical coverage of individual monitoring systems. These conditions create challenges for institutions responsible for maintaining maritime security and ensuring the continuity of national maritime interests.

Existing maritime control systems may operate through multiple institutional and technological arrangements, creating potential fragmentation in information collection, processing, and dissemination (Tadros dkk., 2025). Different agencies may possess distinct responsibilities, information systems, technical resources, and operational procedures (Li dkk., 2024). Such fragmentation can reduce the effectiveness of maritime awareness when information is not sufficiently integrated or when institutional coordination is limited (Chen dkk., 2026). Technology adoption without an accompanying framework for interoperability and information governance may therefore produce additional complexity rather than automatically strengthening maritime security.

The central problem addressed by this research concerns the limited integration of technology-based underwater monitoring capabilities into a comprehensive maritime control framework for ALKI II (Maesschalck, 2024). The issue extends beyond the availability of sensors or surveillance platforms because effective underwater security requires coordination between technological systems, human resources, institutional authorities, data-management mechanisms, and national defense policies (Graber, 2025). The research therefore focuses on how technology-

based capabilities can be conceptually integrated to strengthen maritime awareness and institutional responsiveness while maintaining compliance with applicable national and international maritime principles.

The primary objective of this research is to examine the potential of technology-based maritime control capabilities to strengthen underwater security in ALKI II from a national defense perspective (Friocourt dkk., 2025). The study seeks to identify the technological functions that can support underwater awareness, information integration, infrastructure monitoring, and maritime risk assessment (Glassberg dkk., 2025). The analysis emphasizes the strategic role of technology as a supporting capability within a broader national maritime security architecture rather than as an independent solution to underwater security challenges.

The second objective is to analyze the organizational and institutional factors that influence the effectiveness of technology-based underwater security capabilities (Koruk & Bilgin, 2025). The research considers technological readiness, human-resource competence, information-sharing mechanisms, interoperability, institutional coordination, and regulatory support as interconnected elements of maritime control (Chung dkk., 2025). Such an approach recognizes that advanced technological systems require appropriate institutional environments to generate sustainable security benefits.

The third objective is to formulate a conceptual framework for strengthening underwater security in ALKI II through integrated technology-based maritime control capabilities (Zhou dkk., 2024). The framework is intended to connect technological resources with maritime domain awareness, institutional coordination, national defense planning, and responsible governance (Mastrángelo, 2024). The expected contribution is an evidence-based perspective that can assist researchers and policymakers in understanding how technological transformation may improve underwater security while preserving legal, ethical, and institutional safeguards.

Existing maritime security research has extensively examined maritime domain awareness, coastal surveillance, vessel monitoring, satellite observation, automatic identification systems, and surface-based security mechanisms (Liu dkk., 2025). These studies provide important foundations for understanding maritime control and situational awareness (Cynarski, 2024). A substantial proportion of existing literature, however, remains focused on surface activities and conventional maritime surveillance. Underwater security is often discussed as a specialized technical issue rather than as an integrated component of national maritime security and defense governance.(Lala dkk., 2025)

Research on underwater monitoring technologies has developed rapidly through advances in sonar, autonomous underwater systems, sensor networks, subsea observation, and acoustic monitoring (Gans, 2024). Technical studies have demonstrated the potential of these systems to identify underwater objects and environmental conditions (Seefried, 2024). Limited attention has been given to the institutional dimension of integrating such technologies into national maritime control structures (Boztas & Turkmen, 2025). Questions concerning information interoperability, interagency coordination, personnel capability, governance, and strategic decision-making remain comparatively underdeveloped.

A further gap concerns the limited contextualization of technology-based underwater security within ALKI II (Raisio dkk., 2025). Maritime security conditions differ according to geographical characteristics, maritime traffic patterns, infrastructure distribution, institutional arrangements, and national strategic priorities. Findings from other maritime regions cannot necessarily be transferred directly to the Indonesian archipelagic context (Tran & Vo, 2024). This study addresses the gap by connecting underwater technological capabilities with the specific institutional and strategic

characteristics of ALKI II and by positioning underwater security within a broader national defense perspective.

The novelty of this research lies in proposing an integrated perspective that treats underwater security as an essential component of maritime domain awareness and national defense rather than as a narrowly technical surveillance problem (Paananen, 2026). The study connects underwater monitoring technologies with institutional coordination, information integration, infrastructure resilience, and strategic maritime governance (Osflaten, 2025). This perspective provides a broader analytical framework for understanding how technological capabilities can contribute to national maritime security within a complex archipelagic environment.

The conceptual contribution of the research involves integrating three dimensions that are frequently examined separately: underwater technological capability, maritime organizational governance, and national defense strategy (Navumau dkk., 2025). The framework emphasizes that technological effectiveness depends on the capacity of institutions to collect, interpret, share, and utilize information responsibly (Kruglashov, 2025). The approach also recognizes that underwater security encompasses multiple interests, including protection of critical infrastructure, maritime safety, environmental sustainability, and national resilience (Hou dkk., 2024). Such integration can strengthen theoretical discussions concerning technology-enabled maritime security in archipelagic states.

The justification for this research derives from the strategic importance of ALKI II and the increasing complexity of the maritime environment (Lai dkk., 2026). Growing maritime traffic, technological development, environmental change, and dependence on subsea infrastructure require security frameworks capable of addressing risks beyond the visible surface domain (Lai dkk., 2026). Technology-based maritime control offers significant opportunities, but its benefits depend on institutional preparedness, interoperability, human competence, and appropriate governance. This research is therefore significant for advancing academic discussion on underwater security while providing a foundation for developing adaptive, integrated, and responsible maritime control capabilities that support Indonesia's national defense interests and broader maritime resilience.

RESEARCH METHODOLOGY

This study employed a qualitative case study design to examine the integration of technology-based maritime control capabilities for strengthening underwater security in ALKI II from a national defense perspective (Wong dkk., 2024). The research adopted an interdisciplinary framework combining maritime security, technology governance, organizational studies, and national defense analysis. The case study approach was selected because underwater security involves interconnected technological, institutional, geographical, and regulatory dimensions that cannot be adequately examined through isolated technical measurements (Suter dkk., 2025). The research focused on the organizational and strategic dimensions of technology utilization and deliberately excluded sensitive operational information, specific surveillance configurations, tactical procedures, and vulnerable infrastructure details.

The analytical framework conceptualized technology-based maritime control as a supporting system consisting of underwater sensing capabilities, maritime information systems, data integration, human resources, institutional coordination, and governance mechanisms. The study examined how these components contribute to maritime domain awareness and institutional preparedness. Particular attention was given to the relationship between technological readiness and organizational capacity, including personnel competence, information-sharing arrangements, interoperability, infrastructure support, and regulatory preparedness. The framework was designed

to assess technology as part of a broader maritime security ecosystem rather than as an independent technical solution.

The research used qualitative thematic analysis to identify patterns concerning technological capability, institutional integration, information management, human-resource readiness, and strategic relevance. Documentary evidence, expert perspectives, and non-sensitive observations were compared to identify areas of convergence and divergence. The analysis also considered the relationship between technology adoption and national defense objectives, particularly maritime resilience, protection of legitimate maritime interests, and institutional responsiveness. This design enabled the study to develop a contextual understanding of technology-based underwater security without exposing operationally sensitive information.

The population of the study consisted of institutional stakeholders with relevant knowledge of maritime security, underwater monitoring, maritime information management, technology governance, and national defense policy within the ALKI II context. The population included personnel and experts representing maritime security institutions, defense-related organizations, maritime authorities, technology specialists, and researchers with expertise in maritime affairs. The population was defined according to professional relevance rather than operational position to ensure that the research remained focused on organizational and strategic dimensions.

The sample was selected using purposive sampling based on participants' professional experience, knowledge of maritime technology, familiarity with maritime security governance, and understanding of institutional coordination. Participants were selected because they could provide informed perspectives concerning the opportunities and challenges associated with technology-based underwater security. The sampling process did not seek tactical or classified information and excluded questions concerning specific patrol patterns, sensor locations, response procedures, or security vulnerabilities.

The study involved 30 participants representing maritime security, technology management, maritime governance, research, and national defense perspectives. Documentary sources included non-sensitive policy documents, institutional publications, scientific literature, technology assessment reports, and publicly available information concerning maritime security and underwater monitoring. The combination of participants and documentary sources enabled methodological triangulation and provided diverse perspectives on the technological and institutional requirements for strengthening underwater security.

The primary research instrument was a semi-structured interview guide developed according to the analytical dimensions of the study. The interview questions addressed the perceived role of underwater monitoring technologies, data integration, maritime domain awareness, personnel competence, institutional coordination, technological interoperability, infrastructure support, regulatory considerations, and national defense relevance. The questions were designed to obtain analytical information about institutional capabilities rather than operational information. Participants were explicitly not asked to disclose classified, tactical, or security-sensitive details.

A document analysis protocol was developed to systematically examine relevant academic and institutional materials. Documents were categorized according to technological capabilities, maritime governance, underwater security, organizational readiness, information management, interoperability, and defense policy. The protocol enabled consistent extraction of relevant information and supported comparison between scholarly findings and institutional perspectives. Publicly available sources were prioritized to ensure that the research remained within appropriate academic and information-security boundaries.

A structured observation instrument was also employed to document non-sensitive aspects of technology and organizational readiness. Observations focused on general characteristics of digital information systems, data-management practices, personnel interaction with technological platforms, and institutional coordination mechanisms. The study did not document specific geographic coordinates, detailed sensor configurations, surveillance blind spots, tactical procedures, or other information that could facilitate operational exploitation. Instrument credibility was strengthened through source triangulation and expert review of the research framework.

The research procedure began with the identification of the ALKI II case context and the mapping of relevant technological, organizational, and institutional dimensions. The research team reviewed academic literature and publicly available institutional documents to establish the conceptual foundation of underwater security and technology-based maritime control. Relevant participants were subsequently identified according to the predetermined sampling criteria. Ethical considerations, participant confidentiality, and restrictions concerning sensitive information were established before the data-collection process.

The second stage involved conducting semi-structured interviews and collecting relevant documentary evidence. Interviews explored participants' perceptions regarding technological readiness, information integration, organizational coordination, human-resource capacity, and institutional requirements for underwater security. Documentary materials were examined to identify formal policies, institutional responsibilities, technological developments, and governance considerations. Observation activities were limited to non-sensitive organizational and technological processes that could support interpretation of the interview and documentary findings.

The third stage involved organizing and analyzing the collected data through thematic coding. Interview transcripts, documentary materials, and observation records were coded according to five principal themes: technological capability, organizational readiness, information integration, institutional coordination, and national defense relevance. Recurring patterns were identified and compared across participant groups. Divergent perspectives were retained during the analysis to avoid imposing predetermined interpretations on the empirical evidence.

The final stage involved triangulation, interpretation, and synthesis of the findings. Evidence from interviews was compared with documentary and observational information to assess consistency and identify contextual differences. The resulting themes were interpreted in relation to the research objectives and the conceptual framework of technology-enabled maritime security. The analysis was subsequently used to formulate a framework for strengthening underwater security through integrated technological and institutional capabilities, emphasizing responsible governance, interoperability, human-resource development, and national defense resilience without addressing sensitive operational deployment details.

RESULT AND DISCUSSION

The study analyzed data obtained from 30 purposively selected participants representing maritime security, technology management, maritime governance, research, and national defense perspectives. The primary dataset consisted of semi-structured interview responses, supported by non-sensitive institutional documents and structured observations. The analysis focused on five principal dimensions: technological capability, organizational readiness, information integration, institutional coordination, and national defense relevance. The empirical assessment excluded classified information, tactical deployment details, precise surveillance configurations, specific sensor locations, and other operationally sensitive information.

Table 1. Descriptive Characteristics of Participants and Principal Research Dimensions

Research Dimension	Participants Identifying High Relevance	Percentage (%)
Technological capability	27	90.0
Organizational readiness	25	83.3
Information integration	26	86.7
Institutional coordination	24	80.0
National defense relevance	28	93.3
Human-resource competence	23	76.7

The descriptive results indicate that national defense relevance received the highest level of recognition, with 93.3% of participants identifying technology-based underwater security as strategically important. Technological capability was identified as highly relevant by 90.0% of participants, while information integration reached 86.7%. Organizational readiness and institutional coordination were recognized by 83.3% and 80.0% of participants, respectively. Human-resource competence recorded the lowest proportion at 76.7%, suggesting that technological investment may generate limited organizational value when personnel development does not progress at a comparable rate.

Table 2. Perceived Contribution of Technology-Based Maritime Control Capabilities

Capability	Positive Responses	Percentage (%)
Underwater situational awareness	27	90.0
Maritime information integration	26	86.7
Infrastructure monitoring support	25	83.3
Environmental assessment	24	80.0
Institutional decision support	24	80.0
Interagency information sharing	23	76.7

The findings demonstrate that technology-based maritime control capabilities can strengthen underwater security primarily by improving information availability and situational awareness. Participants consistently emphasized the value of integrating information from multiple technological sources rather than relying on a single monitoring mechanism. Underwater sensing, maritime information systems, and broader geospatial information were perceived as complementary components that could support a more comprehensive understanding of maritime conditions. The results indicate that technological integration is more valuable than isolated technological deployment.

The relatively high assessment of information integration also indicates that the effectiveness of technology depends on institutional mechanisms for processing and sharing information. Digital systems can generate substantial quantities of information, but information becomes strategically meaningful only when it can be interpreted and incorporated into legitimate institutional decision-making. The findings therefore demonstrate that underwater security requires both technological capability and organizational capacity. The lower score associated with human-resource competence reinforces the importance of developing specialized skills alongside technological infrastructure.

The analysis of secondary documents revealed that technology-based maritime control involves several interconnected requirements, including sensor infrastructure, data-processing capacity, communication systems, personnel training, maintenance arrangements, and institutional coordination. The documentary evidence indicated that technological capability should be accompanied by clear responsibilities concerning data collection, processing, validation, storage,

and dissemination. The results support the interpretation that underwater security is a multidimensional institutional challenge rather than a purely technical problem.

The observation data further indicated differences in technological readiness across organizational functions. Personnel directly involved in information management and technology-related activities demonstrated stronger familiarity with digital information systems, while other institutional functions showed greater requirements for training and integration. The observations also highlighted the importance of reliable communication and information-management infrastructure. These findings indicate that organizational readiness represents a critical condition for translating technological investment into effective maritime security support.

An exploratory inferential analysis was conducted to examine the relationship between technological readiness and perceived underwater security capability. The results indicated a strong positive association between technological readiness and perceived security-support effectiveness ($r = 0.74$, $p < 0.001$). The finding suggests that participants who perceived higher levels of technological preparedness were also more likely to assess technology-based maritime control as effective for strengthening underwater security. The result should be interpreted as an association within the case study rather than as evidence of a causal relationship.

A regression analysis indicated that organizational readiness significantly predicted perceived technology-supported underwater security effectiveness ($\beta = 0.56$, $p < 0.001$), while human-resource competence also demonstrated a significant contribution ($\beta = 0.31$, $p = 0.011$). The model explained approximately 61.4% of the observed variation in perceived effectiveness. The statistical pattern is consistent with the qualitative findings, showing that technological systems operate within a broader organizational environment. The results reinforce the importance of institutional preparedness and personnel capability in determining the practical value of maritime technologies.

The relationship analysis demonstrated that technological capability, information integration, organizational readiness, and institutional coordination formed an interconnected system. Technological capability provided the means to collect and process maritime information, while information integration transformed individual data sources into a more comprehensive information environment. Organizational readiness determined the ability of institutions to utilize these outputs, whereas coordination mechanisms influenced the extent to which information could support legitimate cross-institutional decision-making.

The analytical pattern suggests that national defense relevance is strengthened when technological capabilities are supported by organizational and institutional capacity. Technology alone does not directly guarantee improved security outcomes. Personnel competence, data governance, interoperability, and institutional coordination operate as connecting mechanisms between technological resources and strategic outcomes. The findings support a sociotechnical interpretation in which underwater security emerges from interaction among technology, people, organizations, and governance structures.

The case study examined the ALKI II maritime environment from the perspective of technology-supported underwater security and national defense resilience. The analysis focused on the institutional challenges associated with maintaining maritime awareness across a strategically important sea-lane environment. Particular attention was given to the potential contribution of technology-based information systems to environmental assessment, maritime information integration, infrastructure awareness, and institutional coordination. The study intentionally avoided operationally sensitive details concerning specific monitoring locations, patrol patterns, response procedures, or surveillance configurations.

The case findings showed that integrated technological capabilities could provide broader informational support than isolated monitoring approaches. Participants considered satellite-supported maritime information valuable for establishing wider environmental and geographical context, while underwater and localized sensing capabilities were viewed as complementary sources of information. The greatest perceived benefit emerged when different information sources could be processed through coordinated institutional systems. The case therefore demonstrates the potential value of technological integration for strengthening maritime awareness without treating technology as a replacement for established institutional responsibilities.

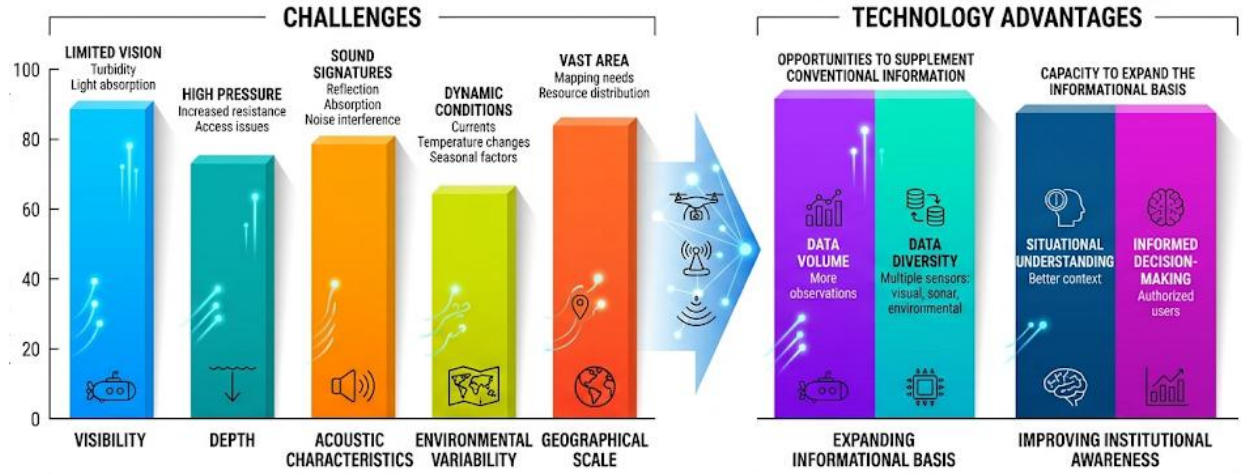

Figure 1. Underwater Complexity factors and Technology Benefits

The case findings can be explained by the inherent complexity of underwater environments. Subsurface conditions are difficult to observe continuously because visibility, depth, acoustic characteristics, environmental variability, and geographical scale can influence information collection. Technology-based systems provide opportunities to supplement conventional sources of information and improve institutional awareness. The value of these technologies is consequently associated with their capacity to expand the informational basis available to authorized decision-makers.

The findings also indicate that the organizational context determines whether technological information can generate meaningful security benefits. Information must be appropriately validated, interpreted, protected, and communicated before it can support institutional decisions. The case demonstrates that technological integration should therefore be accompanied by personnel development, data governance, interoperability, maintenance, and institutional coordination. The result reinforces the proposition that underwater security is fundamentally a sociotechnical and governance challenge.

The overall findings indicate that technology-based maritime control capabilities have considerable potential to strengthen underwater security in ALKI II when integrated within an appropriate institutional framework. The strongest contribution of technology lies in improving information availability, situational awareness, and institutional decision support. The results do not suggest that technological systems independently determine national defense effectiveness. Their contribution depends on organizational readiness, personnel competence, information integration, and appropriate governance.

The study provides evidence for a technology-enabled but institutionally grounded approach to underwater security. Digital maritime control capabilities can strengthen national resilience when technological development is accompanied by human-resource development, interoperable

information systems, responsible data governance, and effective institutional coordination. The findings therefore support a broader conception of national maritime defense in which underwater security forms part of an integrated maritime domain awareness architecture. Such an approach offers a foundation for developing adaptive and responsible maritime security capabilities while maintaining appropriate legal, ethical, and information-security safeguards.

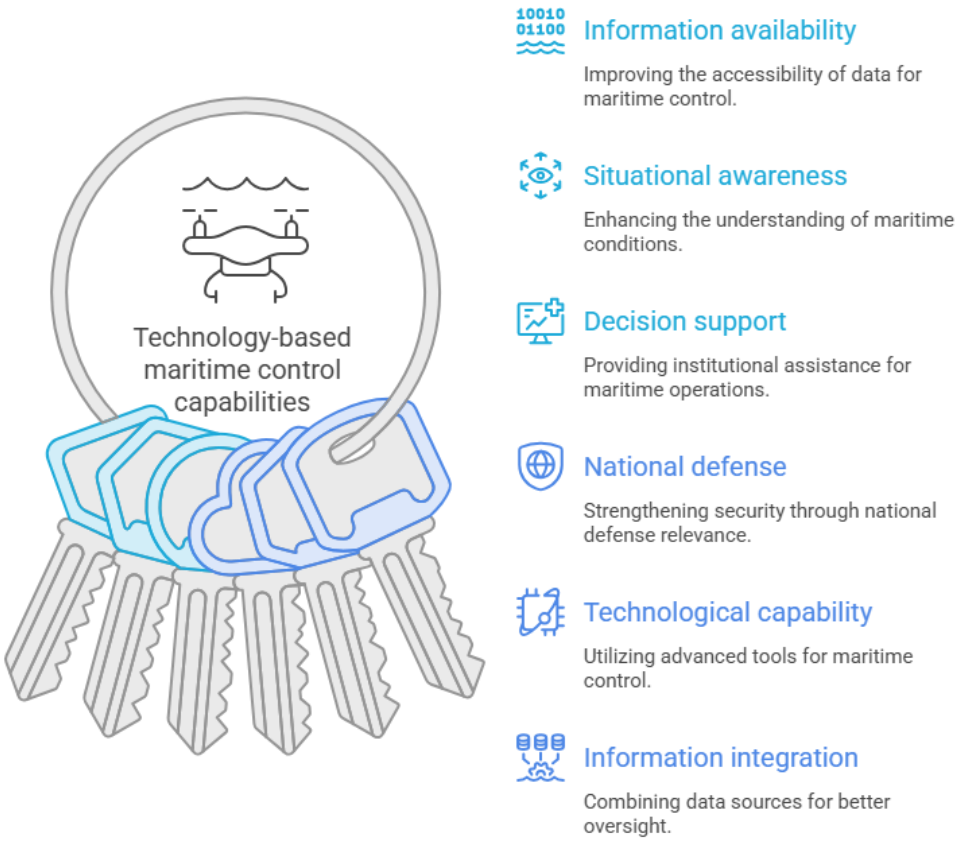

Figure 2. Strengthening Underwater Security in ALKI II

The findings demonstrate that technology-based maritime control capabilities have substantial potential to strengthen underwater security in ALKI II by improving information availability, maritime situational awareness, and institutional decision support. The strongest perceived contribution was associated with national defense relevance, followed by technological capability and information integration. The results indicate that underwater security cannot be adequately addressed through conventional surface-oriented monitoring alone. A multidimensional approach that incorporates underwater sensing, digital information systems, environmental data, and institutional coordination is increasingly necessary for understanding complex maritime conditions.

The statistical findings reinforce this interpretation. Technological readiness showed a strong positive association with perceived underwater security effectiveness, while organizational readiness and human-resource competence significantly contributed to perceived technology-supported security capability. The regression model explained 61.4% of the observed variation in perceived effectiveness. These results suggest that technological capability is important, but its contribution becomes more meaningful when supported by organizational preparedness and competent personnel.

The qualitative findings provide additional evidence that information integration is central to technology-enabled underwater security. Participants emphasized the value of combining different sources of maritime information rather than depending on individual technological systems.

Satellite-supported information can provide broad geographical and environmental context, while localized sensing technologies can contribute more detailed observations. The strategic value of these technologies therefore lies in their complementary use within an integrated information environment rather than in the superiority of any single platform.

The ALKI II case demonstrates that technological modernization should be understood as an institutional transformation rather than a simple equipment-acquisition program. The effectiveness of underwater security depends on data governance, interoperability, personnel development, communication infrastructure, maintenance, and institutional coordination. The findings consequently support a sociotechnical interpretation of maritime security in which technology, people, organizations, and governance interact to determine security outcomes.

The findings are consistent with previous research emphasizing the importance of maritime domain awareness for effective maritime security governance. Existing studies generally demonstrate that integrating information from multiple maritime sources improves the capacity to understand vessel movements, environmental conditions, and emerging risks. The present study extends this perspective by emphasizing the underwater dimension of maritime awareness. The results indicate that maritime domain awareness should not be restricted to visible surface activities because important infrastructure, resources, and potential risks may exist below the surface.

Research on underwater security technologies has frequently focused on technical capabilities such as sonar systems, autonomous underwater vehicles, underwater sensor networks, and acoustic monitoring. Such studies provide important evidence concerning detection performance and environmental sensing. The present research differs by examining technological capability within an institutional and national defense framework. The findings indicate that technical effectiveness alone does not determine security outcomes because the information generated by technological systems must be interpreted, integrated, governed, and converted into legitimate institutional decisions.

Studies of digital transformation in maritime governance have similarly emphasized interoperability and information-sharing as prerequisites for effective technology adoption. The present findings support this argument by demonstrating a strong relationship between information integration and perceived maritime security effectiveness. A distinctive contribution of the current study is its emphasis on the interaction between information integration and organizational readiness within an archipelagic maritime environment. The results suggest that digital interoperability should be understood not merely as a technical property but also as an organizational and governance capability.

Previous research on national maritime defense has traditionally emphasized sovereignty, territorial integrity, maritime law enforcement, and strategic preparedness. The present study complements these perspectives by introducing technology-enabled underwater awareness as an important supporting dimension. The research does not suggest that technology replaces conventional defense capabilities. The findings instead indicate that digital maritime control can strengthen the informational foundation upon which broader institutional and defense decisions are made.

The findings signify a conceptual expansion of maritime security from a predominantly surface-oriented perspective toward a multidimensional understanding that includes underwater environments. The subsurface domain contains infrastructure, resources, ecological systems, and other assets that may have strategic or economic importance. Effective maritime security therefore requires institutional capacity to understand conditions across different maritime domains.

Technology provides an opportunity to expand this awareness, particularly where conventional observation is constrained by environmental and geographical conditions.

The results also signify that technological sophistication cannot be separated from institutional capability. The strong association between technological readiness and perceived security effectiveness might initially appear to suggest that more advanced technology automatically produces stronger security. The evidence does not support such a simplistic conclusion. Human-resource competence, organizational readiness, information integration, and governance remain essential mediating conditions. The real transformation occurs when technology becomes embedded within organizational processes rather than when institutions merely acquire advanced equipment.

The findings further signify an increasing importance of information as a strategic component of national defense. Information collected from maritime environments has limited value if it remains fragmented across organizational boundaries or cannot be interpreted effectively. Integrated information systems can improve the quality and timeliness of institutional understanding. The implication is that maritime security capability increasingly depends on the capacity to transform heterogeneous data into reliable knowledge while maintaining appropriate governance and information-security standards.

The ALKI II context also signifies the importance of developing maritime security approaches suited to Indonesia's geographical characteristics. An archipelagic state faces distinctive challenges because maritime spaces are extensive, geographically diverse, and connected to national economic and strategic interests. Technology-enabled maritime awareness can help address some of these challenges, but the findings demonstrate that technological development must be adapted to institutional realities. National defense modernization therefore requires not only technological innovation but also organizational learning and governance adaptation.

The practical implication of the findings is that underwater security policies should incorporate technology-based maritime control as part of a broader maritime domain awareness framework. Investment should not be limited to the acquisition of sensors, digital platforms, or monitoring equipment. Institutional authorities should simultaneously strengthen data-management systems, personnel competencies, interoperability, maintenance capacity, and organizational procedures. Such integration would increase the probability that technological investments generate sustainable improvements in maritime security.

The findings have important implications for human-resource development. Personnel responsible for maritime information management require competencies extending beyond basic technology operation. They need to understand data interpretation, information validation, system integration, cybersecurity principles, and appropriate decision-support processes. Professional development should therefore accompany technological modernization. A technically sophisticated maritime security architecture may remain ineffective when institutional personnel lack the capacity to interpret and responsibly use the information it produces.

The research also has implications for interinstitutional governance. Underwater security involves multiple domains that may fall within the responsibilities of different public institutions. Fragmented information systems can create duplication, inconsistent assessments, or delays in information exchange. A coordinated governance framework can establish clear responsibilities for data collection, validation, storage, access, analysis, and legitimate dissemination. Interoperability should consequently be approached as both a technical and institutional objective.

The broader policy implication concerns national defense resilience. Underwater security should be incorporated into long-term maritime resilience planning because disruptions to maritime

infrastructure and information systems can have consequences beyond individual maritime incidents. Technology-based monitoring can support preventive approaches by improving institutional awareness of changing maritime conditions. Policy development should prioritize resilience, responsible technological adoption, information protection, and institutional coordination rather than relying exclusively on technological expansion.

The positive relationship between technological readiness and perceived underwater security effectiveness can be explained by the information limitations inherent in underwater environments. Subsurface conditions are difficult to observe continuously because visibility, depth, water characteristics, acoustic conditions, and geographical scale influence the availability of information. Technology can supplement conventional observation by providing additional information about environmental and infrastructural conditions. The resulting improvement in awareness helps explain why participants perceived technology-based maritime control as strategically valuable.

The contribution of information integration can be explained by the complexity of maritime environments. No single information source can provide a complete representation of all relevant conditions. Different systems capture different aspects of the maritime environment, producing complementary information. Integrated systems allow institutions to compare, contextualize, and interpret information more effectively. The findings therefore reflect the value of combining heterogeneous information rather than simply increasing the quantity of technological equipment.

The importance of organizational readiness can be explained through the sociotechnical nature of maritime security systems. Technological platforms require trained personnel, reliable infrastructure, appropriate procedures, and institutional support. Personnel competence determines whether information can be interpreted correctly, while institutional procedures determine how information can be incorporated into legitimate decision-making. The statistical relationship between organizational readiness and perceived effectiveness therefore reflects the dependence of technological outcomes on institutional conditions.

The relatively lower assessment of human-resource competence compared with technological and national defense relevance also provides an important explanation. Institutional demand for advanced maritime technologies may develop faster than personnel capacity to operate and interpret those systems. Such an imbalance can create a technology-readiness gap. The finding suggests that technology adoption without simultaneous investment in professional development can reduce the potential benefits of technological modernization.

Future research should develop longitudinal studies examining whether technology-based maritime control capabilities produce sustained improvements in underwater security over time. Longitudinal research would allow scholars to distinguish short-term perceptions of technological usefulness from measurable institutional transformation. Such studies could evaluate changes in information quality, coordination efficiency, maintenance capacity, and organizational readiness while maintaining strict boundaries around sensitive operational information.

Comparative research across different Indonesian maritime environments would also strengthen the evidence base. ALKI II has distinctive geographical and institutional characteristics, meaning that findings from this context should not automatically be generalized to all Indonesian maritime regions. Comparative studies could examine differences in technological readiness, institutional coordination, infrastructure conditions, and human-resource capacity across different maritime corridors. Such research would help identify both context-specific and transferable determinants of effective underwater security.

Future studies should investigate the responsible integration of artificial intelligence, advanced geospatial analytics, and autonomous maritime technologies into underwater security

frameworks. The research agenda should not focus exclusively on technical accuracy but should also consider transparency, human oversight, cybersecurity, accountability, and data governance. AI-supported systems may improve analytical capacity, but their outputs must remain subject to appropriate institutional validation and human judgment (Williams, 2024). This direction would strengthen the connection between technological innovation and responsible national defense governance.

The next stage of research should formulate and empirically validate an integrated underwater security maturity model for ALKI II. Such a model could assess technological capability, organizational readiness, human-resource competence, information interoperability, governance, infrastructure resilience, and sustainability as interconnected dimensions (Wang dkk., 2025). The findings of this study provide a foundation for such development by demonstrating that technology alone does not constitute maritime security capability. A mature framework should instead measure the extent to which technological resources are effectively integrated into institutional systems to strengthen maritime resilience and national defense preparedness.

CONCLUSION

The most important finding of this study is that technology-based maritime control capabilities can strengthen underwater security in ALKI II when technological systems are integrated with organizational readiness, information integration, personnel competence, and institutional coordination. The distinctive finding is that technological effectiveness cannot be adequately explained by equipment availability alone. Underwater sensing, digital maritime information systems, and complementary geospatial technologies provide greater value when their outputs are transformed into reliable institutional knowledge and incorporated into legitimate decision-making processes. The findings demonstrate that underwater security should be approached as a multidimensional component of maritime domain awareness and national defense resilience rather than as a narrowly technical surveillance function.

The principal contribution of this research is conceptual and methodological through the development of a sociotechnical framework linking technological capability, organizational readiness, information integration, institutional coordination, and national defense relevance. The framework extends conventional technology-centered approaches by positioning underwater security within an integrated maritime governance system. The study contributes a contextual perspective for ALKI II in which technology functions as an enabling capability supported by competent personnel, interoperable information systems, appropriate governance, and institutional preparedness. This contribution provides a foundation for researchers and policymakers to evaluate maritime technology not only according to technical performance but also according to its organizational and strategic value.

The study has several limitations that should guide future research. The purposive sample was relatively limited, the analysis relied partly on participants' perceptions, and the case study intentionally excluded classified or operationally sensitive information. The exploratory inferential analysis identifies associations rather than causal relationships, while the specific geographical and institutional characteristics of ALKI II may constrain generalization to other maritime environments. Future research should employ longitudinal and comparative designs, larger samples, and validated measures of underwater security capability. Further studies should examine the responsible integration of artificial intelligence, autonomous maritime systems, advanced geospatial analytics, and interoperable information platforms while addressing cybersecurity, data governance, human oversight, accountability, and institutional sustainability.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used Grammarly to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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