



# Geospatial intelligent analysis to support Indonesian airspace defense

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## ABSTRACT

**Background:** In the modern era, air defense plays a critical role in national security strategies, especially for Indonesia, the world's largest archipelagic nation, which faces complex challenges in safeguarding its vast airspace. Geospatial Intelligence (GEOINT) offers advanced capabilities for enhancing detection, mapping, and planning in air defense operations. By utilizing data from satellites, UAVs, and sensor technologies, GEOINT has the potential to significantly improve air defense through real-time data analysis and situational modeling. **Methods:** This study employed a literature review method to examine the role of GEOINT in Indonesia's air defense. Literature from academic sources and official reports was analyzed, focusing on peer-reviewed studies that discuss GEOINT technologies such as UAVs, radar systems, and topographic mapping. The review covered the application of these technologies in threat detection, mission planning, and the surveillance of adversarial activities. **Findings:** The analysis revealed that GEOINT is vital in supporting Indonesia's air defense operations. It enables early threat detection, efficient mission planning, and constant monitoring of adversarial movements using data from satellites and UAVs. Additionally, GEOINT facilitates accurate terrain mapping, optimal flight route planning, and the surveillance of strategic areas, enhancing defense strategies and enabling timely preventive actions against threats. **Conclusion:** GEOINT is an essential strategic tool for enhancing Indonesia's air defense capabilities. To maximize its potential, investments in advanced technologies, geospatial data infrastructure, and personnel training are crucial. Furthermore, international collaboration and the development of monitoring satellites will be pivotal for the future success of Indonesia's air defense strategy. **Novelty/Originality of this article:** This study provides a focused exploration of the integration of GEOINT in Indonesia's air defense strategy, highlighting its transformative impact on threat detection and defense planning. The study underscores the need for technological advancement and international partnerships in strengthening national air defense capabilities.

**KEYWORDS:** airspace defense; geospatial intelligence; remote sensing; satellite imagery; unmanned aerial vehicles.

## 1. Introduction

In modern military operations, especially air defense, the role of Geospatial Intelligence (GEOINT) is very important. Geospatial intelligence (GeoAI) offers a new paradigm for geographic knowledge discovery and data processing, improving the interpretation of complex geomatics data (Pierdicca & Paolanti, 2022). To support air defense in Indonesia GEOINT is needed to get the right information so that decisions are made accordingly. Optimizing the interception strategy of air defense missile systems can significantly reduce the expected costs during the missile target interception process (Gao et al., 2022). GEOINT is essential for detecting, analyzing, and responding to air threats. Successful neutralization

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of air threats requires comprehensive knowledge of resources, enemy intentions, and analysis of vulnerable assets/points to optimize weapon assignments and achieve higher efficiency in military conflicts (Naseem & Ahmad, 2020).

The role of GEOINT to support defense, it is also necessary to consider the infrastructure to support the huge data. Geospatial infrastructure is critical for geospatial technologies to contribute to solving humanity's problems, with a focus on open access, sharing, engagement, web, Big Data, AI, and data science (Dangermond & Goodchild, 2020). GEOINT thus provides accurate and comprehensive information about the physical environment and the activities that occur within it using remote sensing, mapping, and geographic data analysis technologies. The role of GEOINT in air defense should not be underestimated. Capable of providing accurate, real-time information about the enemy's environment and activities, GEOINT forms the backbone of detection, analysis, and response to air threats. To support Air Defense, it is necessary to fulfill Air Force equipment such as radars, fighter aircraft, missiles, and air bases.

## 2. Methods

This study adopts a literature review approach to explore and analyze the role of Geospatial Intelligence (GEOINT) in Indonesia's air defense. The first stage involves establishing research objectives, which include identifying and synthesizing GEOINT-related studies, analyzing relevant technologies such as UAVs and radars, and assessing the potential for GEOINT to enhance mission planning and air threat surveillance. The selected literature is drawn from peer-reviewed sources or official reports published within the last decade, with data sourced from academic databases like Google Scholar, JSTOR, and ScienceDirect. Data collection is conducted through targeted searches using relevant keywords, with sources chosen based on their relevance and quality. Key findings from each source are recorded, allowing for a comprehensive understanding of current research on GEOINT applications in air defense.

In the data analysis stage, key themes such as threat detection and terrain mapping are identified and synthesized to provide a holistic view of GEOINT's contributions to air defense. The findings are then structured into a report comprising an introduction, methodology, key findings, discussion, conclusion, and references. To ensure quality, the report undergoes evaluation and revisions based on feedback. The methodology of this study involves a structured literature search, followed by meticulous data selection and analysis, culminating in report writing and revision. Overall, this approach aims to determine how GEOINT can be optimized to strengthen Indonesia's air defense capabilities.

## 3. Results and Discussion

Indonesia is the largest archipelago in the world with extensive and complex airspace. So it is necessary to apply GEOINT to support the defense of Indonesia's airspace. Geospatial intelligence (GEOINT) has evolved to support military operations by synthesizing information from multiple sources, improving the common operating picture (COP), and enhancing decision-making in military operations (Coorey, 2018). It is important to detect threats early in air defense. In air defense, the first and most important step is to detect threats early, using computational electromagnetics to predict the Radar Cross Section (RCS) of a weapon system (Touzopoulos & Zikidis, 2021). Recognizing tactical intent in multi-aircraft cooperative air combat will improve collaborative decision-making efficiency (Guanglei et al., 2021). The importance of detecting threats early can recognize the threat in Indonesian airspace. In air defense, radar plays a very important role. The proposed method effectively couples aircraft radar cross-section characteristics with trajectory optimization to address radar threats in air defense (Xu et al., 2020). Radar surveillance of unmanned aerial vehicles (UAVs) is growing, with small, low-speed UAVs flying at low and very low altitudes being the most difficult targets to detect (Riabukha, 2020). Beyond radar

using ground-based sensors, unmanned aircraft (UAVs), and satellites, GEOINT enables real-time monitoring of airspace. UAVs can provide accurate terrain information, with flight altitude having a greater impact on accuracy than the number of ground control points (Park et al., 2020). Not only UAVs but satellites can also provide information for GEOINT. Global open data remote sensing satellite missions, such as multispectral satellite missions, radar, and digital elevation models, have high potential for effective and sustainable land use management (Radočaj et al., 2020). With the combination of UAVs and satellites, it is very helpful for GEOINT in obtaining data, even real-time data. Combining unmanned aerial systems (UAS) and satellite data offers value-added possibilities in various earth observation applications, such as data/sensor/temporal fusion, geolocation assistance, and data calibration (Partsinevelos & Su, 2022). This technology enables the detection of flying objects such as enemy warplanes, drones, and ballistic missiles from a distance before they arrive at the intended area. active drone detection systems use millimeter-wave radar on drones to detect, track, and pursue target drones (Dogru & Marques, 2020). GEOINT as a detector requires accurate and fast data to prevent threats. Geospatial Intelligence (GEOINT) analysis can effectively identify terrorist hideouts in mountainous areas, supporting national defense interests (Utomo et al., 2021). Combatant Commands must exploit GEOINT modeling capabilities to improve decision-making and situational understanding in the planning of military operations. Geospatial intelligence and traditional intelligence activities must collaborate to effectively address global security threats and meet the growing need for technological advances in intelligence (Mugavero et al., 2015). GEOINT will help leaders make informed and quick decisions. GEOINT provides leaders with a shared understanding of the operational environment, helping them make informed and quick decisions.

GEOINT combined with mapping can add information on Indonesia's air terrain conditions. For air defense operations, accurate terrain mapping is essential. Accurate terrain mapping is essential for air defense operations to optimally engage SAMs and determine the best set of air vehicle operations (McEneaney et al., 2004). Accurate terrain mapping is essential for air defense operations, as jet noise measurements need to be converted to modeled levels to obtain adequate protection (Mobley et al., 2021). Radar-based mapping systems for obstacle detection and path planning on unmanned aerial systems can improve obstacle avoidance and path planning in air defense operations (Miccinesi et al., 2022). The role of mapping is very important to support GEOINT. For example, with terrain that has been mapped in detail, the military can know the areas that are already strong and the areas that are still weak. Weak areas must be strengthened by the Indonesian National Army (TNI) Detailed topographic data is needed for the placement of radars, missile defense systems, and observation posts due to GEOINT. Accurate terrain mapping is essential for planning military operations, taking into account factors such as topography, land use/land cover, and vehicle mobility (Pundir & Garg, 2020). mapping techniques for off-road traffic capability assessment, focusing on topography and land use/land cover, in support of military operations (Pundir & Garg, 2020). topographic mapping and improving the validation methodology for SAR data, which is essential for locating radars and missile defense systems (Rocca et al., 2021). Dengan pemetaan topografi yang lengkap data yang dihasilkan dapat help in determining the location points of radars and missiles for the defense of Indonesia's airspace. Indonesia can create detailed topographic maps that include elevation, vegetation and man-made structures using data from satellites and UAVs (Unmanned Aerial Vehicles). UAV data can effectively extract spatial information of urban land, including vacant land in urban areas, with high accuracy, thus enhancing various applications in remote sensing and image processing (Shukla & Jain, 2020). UAV-derived topography shows promise for hydraulic modeling in tropical environments, with the potential for accurate terrain modeling and accuracy comparable to high-precision topographic models (Mazzoleni et al., 2020). With UAV technology can be used when mapping the terrain and getting information for GEOINT. Later GEOINT can help TNI to get the right decision results or the right location of a threat. By using GEOINT TNI can find strategic locations for the placement of air defense infrastructure. With the Internet

of Vehicles (IoV) method effectively and precisely estimates the location parameters of moving air targets, helping strategic locations for the placement of air defense infrastructure (Liu, Li, et al., 2022). The method of estimating sensor bias in geographic locations, makes surveillance platforms more effective for precision targeting (Taghavi et al., 2020). By using GEOINT, the TNI can find strategic locations for the placement of air defense infrastructure, thereby reducing the number of standby locations needed compared to previous military estimates. (Bell et al., 2011). GEOINT mapping can also plan safe flight routes for military aircraft. GEOINT provides detailed data analysis, assessment of the operational environment, and a means to investigate problems, improving decision-making in military operations.

Accurate information on the enemy's environment, weather, and location is essential for air defense mission planning. Accurate information on the enemy's environment, weather, and location is critical to air defense mission planning, as it helps to create sleeping lanes on the ground to avoid detection and minimize exposure time for survival (Woo et al., 2022). Accurate information on the environment, weather, and enemy location is essential for air defense mission planning, including UAV flight route planning (Stecz & Gromada, 2020). Accurate information on the environment, weather, and enemy location is essential for air defense mission planning to minimize damage to defended assets (Summers et al., 2020). Accurate information on the environment, weather, and enemy location is critical to air defense mission planning, as it helps generate risk-minimizing flight paths with predetermined flight times (Babel, 2023). Before conducting an air defense mission, complete information support is needed so that the mission is successful and avoids errors. The data needed to plan operations with high precision can be obtained through GEOINT. IoT cloud platforms and big data information mining technology can help plan high-precision operations with better efficiency and scalability (Li, 2022). Geospatial data is generated through applications such as land surveying, remote sensing, mobile mapping, geo-location sensors, and GNSS tracking (Praveen et al., 2016). GEOINT data is useful for planning telecommunications networks and supporting the description, explanation, or forecasting of human activities (Boccardo & Gentili, 2012). GEOINT data can provide solutions and insights into crime mysteries, complex events, and social change over time (Bhattacharya et al., 2013). Data through GEOINT that has been collected in detail will be able to assist in a good planning. For example, before conducting military operations with the help of GEOINT, leaders can make good and precise plans before troops are deployed in the implementation of military and non-military operations. Weather data taken from satellites can be used to determine the best time to carry out attacks or air patrols. Satellite data is used in modern weather forecasting through the assimilation of passive infrared sound data, microwave sound and imaging data, and wind information (Eyre et al., 2022). Satellite data is used in modern weather forecasting to improve forecasts and evaluate the impact of research instruments on numerical weather prediction (Einaudi et al., 2001). Satellite data can be used for efficient passive detection of aerial targets in space-air-ground integrated networks (Liu, Liu, et al., 2022). With weather satellite data, TNI is able to make plans for air defense missions. Flight paths, landing points, and targets can also be planned with the help of digital maps and 3D terrain models. 3D printed models offer visualization advantages and a better understanding of the terrain compared to virtual models or traditional maps for military planning (Solla et al., 2020). Deep Learning can create mapping and generate elevation models from a single RGB satellite image or drone image, making it useful for 3D flight planning and simulation (Panagiotou et al., 2020). GEOINT provides real-time situation updates, allowing strategies to be adjusted during operations. It can also enable monitoring while the mission is in progress.

GEOINT enables efficient surveillance and reconnaissance of enemy actions. GEOINT enables effective surveillance and reconnaissance of enemy activities by using video sensors for aerial surveillance and geo-location of ground targets (Taghavi et al., 2020). Geolocation of enemy transmitters provides threat warnings and enables guided munitions against enemy targets in electronic warfare systems (Khalaf-Allah, 2021). Geolocation and target tracking in wireless and satellite systems can be useful for civilian and military operations

(Elgamoudi et al., 2021). GEO-SAR signals can be used for military and civilian surveillance applications, including aerial, ground, and maritime surveillance (Santi et al., 2021). With technology that can be utilized to conduct surveillance, this can facilitate the TNI in carrying out a mission. This is the role of GEOINT that can be used by the TNI in conducting surveillance and can effectively find enemy hiding places. Indonesia can consistently monitor border areas and other strategic areas through the use of remote sensing technology and drones. A multilayer hybrid architecture based on cameras, scalar sensors, radars, and UAVs can effectively detect intrusions in border areas and efficiently manage networks (Laouira et al., 2021). UAVs have potential for coastal zone management, providing high spatial and temporal resolution to monitor and track changes in coastal environments (Adade et al., 2021). This smart monitoring system integrates UAVs with remote sensing technology to monitor illegal activities along the border (Nijim, 2016). Remote sensing using unattended sensors provides continuous and extensive coverage and is more cost-effective compared to the deployment of personnel in Homeland Defense applications such as border security and military installations (Moldt, 2003). By utilizing UAVs, the TNI can conduct surveillance in border areas or conflict areas. This can be used by the TNI for military or non-military missions. This surveillance helps find suspicious activities such as the placement of anti-aircraft weapons or the construction of military facilities by the enemy. Intelligent vision-based surveillance systems can automate monitoring and alert operators when unusual behavior or events of interest are detected (Tung et al., 2011). Detection of suspicious human activity from surveillance video can help prevent terrorism, accidents, illegal parking, vandalism, fights, crimes, and other suspicious activity (Amrutha et al., 2020). Adversaries target critical infrastructure sectors to undermine military capabilities, readiness, and power projection (Evans, 2020). UAVs and UAS can detect suspicious objects or activities very accurately using Machine Learning and communication schemes (Barik et al., 2022). By utilizing GEOINT through UAVs or unmanned aircraft helps the TNI conduct surveillance of suspected activities in conflict-prone areas. This can accelerate the acquisition of information without having to enter into areas that are inaccessible or conflict areas. UAVs can conduct surveillance as spies to obtain information on suspicious areas or activities. Information is critical to anticipate surprise attacks and plan rapid responses to threats. Game theory can be used to model defenses and attacks in smart grid network security, providing insights to plan rapid responses to threats and anticipate surprise attacks. (Shan & Zhuang, 2020). Therefore, the data and information that has been obtained must be kept safe.

#### 4. Conclusions

Indonesia's airspace defense heavily relies on Geospatial Intelligence (GEOINT) to maintain security and sovereignty. To strengthen air defense capabilities, it is essential to ensure the adequacy of the Air Force's defense assets, including radars, fighter jets, missiles, and strategically located air bases. Leveraging advanced technologies such as UAVs, digital mapping, high-tech radars, and guided missiles will enhance the effectiveness of Indonesia's defense systems. Comprehensive training is also crucial to equip TNI personnel with the skills to interpret and utilize geospatial data effectively in operations. This preparation extends beyond human resources to include the development of GEOINT infrastructure that accelerates the modernization and intelligence of Indonesia's air defense capabilities.

GEOINT provides crucial information and strategic benefits through its real-time threat detection, mapping, planning, and monitoring capabilities. Establishing a robust data infrastructure to store, manage, and analyze geospatial data is imperative, which requires geospatial data centers and sophisticated analytical tools capable of processing inputs from multiple sources. Investments in technology, infrastructure development, personnel training, international collaboration, and the integration of defense systems are all necessary for GEOINT's successful implementation. Additionally, deploying remote sensing satellites to capture high-resolution, real-time imagery will greatly enhance the ability to

detect and monitor threats. International partnerships are essential to share knowledge and advance GEOINT, ultimately fortifying Indonesia's airspace defense against a range of potential threats, including military, non-military, and hybrid challenges.

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Not applicable.

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Not applicable.

### Data Availability Statement

Not applicable.

### Conflicts of Interest

The authors declare no conflict of interest.

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