ESCUELA NAVAL DE CADETES "ALMIRANTE PADILLA"
Honor y Tradición

OnBoard Knowledge Journal

Article

Advantages of Designing and Developing Electro-Optical Systems for the Remote Weapon Stations (RWS) of the Colombian Navy

Ventajas de diseñar y desarrollar sistemas electro-ópticos para las Estaciones de Armas Remotas (RWS) de la Armada Nacional de Colombia

Cristian Jiménez Barrera [1]* Oscar Olaya Vera [2] Mervín Sosa Borrero [3] and Diego Guevara Amaya [4]

[1] Electronic Engineer, Director of the Naval Technological Development Center (CEDNAV), Cartagena, Colombia; cristian.jimenez@armada.mil.co
[2] Electronic Engineer, Head of the Weapon Systems Program, CEDNAV, Cartagena, Colombia; ing.oscar.olaya@gmail.com
[3] Systems Engineer, Head of the Command and Control Systems Program, CEDNAV, Cartagena, Colombia; mervin.sosa@armada.mil.co
[4] Control Engineer, Research Manager of the Command and Control Systems Program, CEDNAV, Cartagena, Colombia; diego.guevara@armada.mil.co

* Correspondence: cristian.jimenez@armada.mil.co

Citation: Jiménez, C.; Olaya, O.; Sosa, M.; Guevara, D. . Advantages of Designing and Developing Electro-Optical Systems for the Remote Weapon Stations (RWS) of the Colombian Navy. *OnBoard Knowledge Journal* **2025**, *1*, 3. https://doi.org/10.70554/OBJK2025.v01n02.05

Received: 01/07/2025, Accepted: 15/10/2025, Published: 11/11/2025

DOI: https://doi.org/10.70554/OBJK2025.v01n02.05

Abstract: The Colombian Navy requires electro-optical systems for its Remote Weapon Stations (RWS), which are essential in defense and security operations. Currently, reliance on foreign suppliers increases the cost of these systems and complicates technical support. Given the previous success of CEDNAV in manufacturing low-caliber RWS installed on vessels built by COTECMAR, there is now a growing need to develop electro-optical systems locally. Such an initiative could enhance operational efficiency, reduce costs, and promote technological independence. This article examines the advantages and challenges of this development, aiming to strengthen national defense capabilities and foster social and economic growth.

Keywords: Colombian Navy; Electro-optical; Military development; Remote Weapon Stations; Technological independence.

Resumen: La Armada Nacional de Colombia necesita sistemas electro-ópticos para sus estaciones de armas remotas (RWS), esenciales en operaciones de defensa y seguridad. Actualmente, la dependencia de proveedores extranjeros encarece estos sistemas y dificulta el soporte técnico. Dado el éxito previo en la fabricación de RWS de bajo calibre por parte de CEDNAV que se instalan en los buques fabricados por COTECMAR, surge la necesidad de desarrollar localmente sistemas electro-ópticos, lo cual podría mejorar la eficiencia operacional, reducir costos y fomentar la independencia tecnológica. Este artículo analiza las ventajas y desafíos de este desarrollo, con miras a fortalecer la capacidad de defensa y el crecimiento social y económico nacional.

Palabras clave: Electro-ópticos; Estaciones de Armas Remotas; Armada Nacional de Colombia; Independencia tecnológica; desarrollo militar.

1. Introduction

The Colombian Navy, in carrying out naval operations for national defense, security, and the protection of maritime and riverine interests, requires electro-optical systems for its afloat units. These systems enable surveillance, monitoring, and target designation tasks for both existing and developing Remote Weapon Stations (RWS).

Currently, the development of electro-optical systems is entirely dependent on foreign manufacturers. This type of technology is costly not only in terms of initial acquisition, but also due to inefficient technical support and post-sale maintenance services provided by foreign suppliers. Furthermore, none of these manufacturers operate repair or maintenance facilities for electro-optical systems within Colombia.

Considering that low-caliber RWS have previously been manufactured domestically by the Naval Technological Development Center (CEDNAV), and that similar projects are currently under development for installation aboard new vessels produced by COTECMAR, it becomes essential to identify the advantages of complementing these efforts with locally developed electro-optical systems. At present, an electro-optical device suitable for RWS applications (12.7 mm and 25 mm calibers) is estimated to cost approximately USD 200,000, representing an indispensable component that must be acquired abroad, thereby exacerbating the challenges associated with cost, technical support, and maintenance.

Technological evolution in the military domain has become a determining factor in national defense capabilities, particularly in the face of increasingly complex and asymmetric threats, as evidenced by ongoing international conflicts. In this context, electro-optical systems play a critical role in detecting, identifying, and neutralizing potential threats, as well as in protecting strategic assets and ensuring civilian security. Market analyses indicate that the growth of the remote weapon station and electro-optical systems sector is driven primarily by increased military investment aimed at technological innovation and modernization, with a notable upward trend in adoption across Latin American naval and land defense sectors.

The author [11] conducted a study indicating that the main factor driving the growth of the remote weapon station and electro-optical system market is the increasing military expenditure aimed at innovating and developing robust weapon systems to revolutionize defense forces worldwide. Furthermore, the study notes that in Latin American countries, there is a growing trend toward the adoption of such technologies within naval and land warfare sectors.

However, despite their importance, questions remain about the efficiency, technological innovation, and socio-economic contributions of these systems. In this sense, it becomes necessary to conduct an analysis to understand the advantages and implications of designing and developing electro-optical systems for the Colombian Navy's Remote Weapon Stations allowing an assessment of whether this scientific endeavor is worthwhile and whether it could lead to the desired technological independence from foreign manufacturers. Such development could enhance naval operational efficiency, reduce mean time between failures, create employment opportunities, and boost national industrial production both within the GSED (Governmental Social and Enterprise of Defense) and among private companies supporting the defense sector.

The structure of this article is organized as follows. Section 2 presents the main contributions of this work, outlining the strategic, technical, and socioeconomic perspectives associated with the local development of electro-optical systems. Section 3 reviews the current state of the art in the design and development of electro-optical systems applicable to naval RWS platforms. Section 4 analyzes the key characteristics and operational capabilities of these systems in modern naval contexts. Section 5 examines the socioeconomic effects of investment in research, development, and innovation. Finally, Section 6 summarizes the main findings and discusses their implications for national defense and technological development.

2. Contributions

This article makes the following main contributions:

i. It provides a strategic analysis of Colombia's technological dependence on foreign suppliers for electro-optical systems used in Remote Weapon Stations (RWS), highlighting the associated economic, operational, and logistical limitations, and justifying the need for indigenous development.
ii. It presents a comprehensive technical and operational characterization of electro-optical systems applicable to naval RWS, including sensor technologies, detection and identification criteria, and key challenges related to stabilization, image latency, and system integration in maritime environments.
iii. It evaluates the socioeconomic and research, development, and innovation (R&D&I) impact of locally developing electro-optical systems, emphasizing job creation, strengthening of the national defense industry, technological independence, and the potential for dual-use civilian and military applications.
iv. It contextualizes the Colombian case within an international framework by analyzing global trends, recent conflicts, and defense policies, providing lessons learned and strategic insights to support national decision-making in the development of indigenous electro-optical capabilities.

3. Current state of the design and development of electro-optical systems for remote weapon stations applicable to the Colombian Navy's developments

An electro-optical system (EOS) is an imaging system used for military or law-enforcement applications that includes sensors operating in the visible and infrared bands. These systems provide comprehensive situational awareness by day and night, and under low-light conditions [4]. In the defense industry, they are typically employed alongside low-caliber direct-fire Remote Weapon Stations (RWS) and integrated into fire control systems and combat management systems.

A common accessory to an electro-optical suite is a motorized, two-axis (or multi-axis) self stabilized platform [13]. However, for the RWS platforms developed by the Naval Technological Development Center of the Colombian Navy, either of the two subsystems may be used. In line with this, the present review will survey the state of the art of non-motorized electro-optical systems, which fall within the scope and objectives of this article.

Since 1958, object detection probability in optical system imagery has been quantified using the metric framework proposed by researcher John Johnson. Although often debated, Johnson's criteria remain in use to define thresholds for detection, recognition, and identification of objects. The theory posits a 50% probability of discriminating an object based on a minimum number of pixels in an image, regardless of the sensor technology—i.e., it applies to daylight cameras (CCD) [22] as well as to infrared night-vision cameras. Another relevant standard is NATO STANAG 4347 (in force since 1995), which refines the detection, recognition, and identification (DRI) concepts by increasing the required probabilities of discrimination for targets of interest [17].

Based on these definitions, any EOS design and development proposed in Colombia for the Navy's RWS must account for recognition and identification classifications regardless of the underlying technology. Otherwise, it would fail to comply with prevailing standards and could not be competitive in international military and commercial contexts.

Electro-optical sensors are those that, through images or video, enable the detection, identification, and tracking of a target of interest [4]. Within the electromagnetic spectrum, these sensors operate in the visible light range perceivable by the human eye (400 nm to 700 nm). Examples include cameras found in cell phones, computers, tablets, or the daylight cameras of closed-circuit television systems.

In the infrared spectrum, there are four operational sub-bands: Near Infrared (NIR), Long Wave Infrared (LWIR), Medium Wave Infrared (MWIR), and Shortwave Infrared (SWIR) [8]. Infrared cameras operating in the lower band, up to 2.5 microns, are commonly used in night vision devices and light-intensifying lenses. Applications in the mid and upper bands, on the other hand, require detectors with cryogenic coolers that lower the detector's temperature to ensure proper image transformation [10]. For this reason, these mid- and long-wave bands are generally selected for naval applications and, specifically in this study, are the ones optimized for the RWS developed in Colombia (see Figure 1). However, these technologies currently face a major limitation: their electronic systems, especially the cryogenic ones, have a service life of approximately 4,000 operating hours.

Figure 1. RWS developed by Colombia, Barracuda Shooting System.
Source: The authors.

Laser rangefinders are COTS devices with military-grade specifications authorized by NATO (1995). They use laser light at eye-safe wavelengths (1540 nm, Class 1) and are available from multiple manufacturers in a variety of models according to their measurement range. Most of these devices include communication protocols that allow integration with electro-optical assemblies. For Colombian RWS platforms, electro-optical systems are required to include rangefinders with this technology and a maximum range of 10 km, considering that the maximum firing range of 25 mm RWS cannons is approximately 7 km.

In 2005, the Spanish company INDRA established a maintenance department for optical equipment. Two years later, having gained experience and received specialized training from various manufacturers, laboratories, and testing centers, the company produced its first electro-optical system in 2017, based on the integration of electronic and optical components. To date, INDRA offers a wide range of electro-optical products, performs maintenance on its own systems, and is certified to repair systems from other manufacturers.

In 2017, the global remote weapon station market was valued at USD 7.67 billion, with projections to reach USD 14.42 billion by 2023 [15]. Companies competing in the RWS market seek to offer the most attractive features for a wide range of customers, such as support for multiple weapon types and calibers, automatic stabilization, single or multi-weapon configurations, modularity, rapid reconfiguration (weapon/sensor), ease of integration, user-friendly operation, and simplified training.

The development and commercialization of military electro-optical systems were severely affected in 2022 by the COVID-19 pandemic, which disrupted the supply chain of electronic components. As a result, several manufacturers reduced production levels. However, the pandemic also reaffirmed the need for these technologies and accelerated the push toward developing more efficient systems for all combat scenarios and dual-use applications.

A study conducted by [10] on military electro-optical and infrared systems for portable applications, vehicles, and RWS platforms forecasts the global market through 2031, based on data from companies such as Leonardo, BAE Systems, Thales, Teledyne FLIR, and L3Harris. The study predicts that Latin America will experience a 67.5% increase in the adoption of electro-optical systems for military applications over the next decade compared to 2017 levels.

4. Characteristics of electro-optical systems for naval Remote Weapon Stations (RWS) and their respective capabilities, including their contribution to surveillance, detection, and threat deterrence

4.1. Modern applications in ship design and development

The development of new warships has been driven by the need to integrate essential sensors such as radars. However, the growing trend toward incorporating advanced electro-optical systems has complemented naval platforms, ensuring they remain at the forefront of technology. Shipyards have adopted innovative approaches to vessel design, seeking to maximize the efficiency of electro-optical systems onboard. The integration of these systems is essential not only for improving the accuracy of fire control systems but also for enhancing surveillance, target acquisition, and defensive capabilities in complex maritime environments.

The ability to operate effectively in challenging maritime conditions, where weather and vessel movement present constant obstacles, has encouraged ship designers to develop technologies that stabilize and optimize onboard electro-optical systems. Furthermore, the incorporation of laser technologies, artificial intelligence, and optronics in modern ships enables improved weapon control and greater efficiency in naval combat. In this way, electro-optical systems not only enhance the operational capacity of ships but also ensure that navies maintain a tactical advantage in an increasingly competitive maritime domain (Pagonis, 2024).

4.2. Current trends and tactical uses of electro-optical systems in the Russia–Ukraine war

The war in Ukraine has provided a unique scenario for assessing current trends in the use of electro-optical systems and their application in weapon systems. Both Ukrainian and Russian armed forces have integrated advanced electro-optical systems into their tactical and operational outcomes, highlighting the crucial role these technologies play in modern warfare. In particular, weapon systems equipped with electro-optics have been used to carry out precise and controlled strikes, even under challenging conditions.

This conflict has seen extensive use of drones and unmanned aerial vehicles equipped with electro-optical sensors, allowing operators to obtain real-time information from the battlefield [5]. This not only facilitates target acquisition and tracking but also enables more accurate artillery fire adjustment, Remote Weapon Station (RWS) assignment, and missile targeting. These trends suggest that electro-optical systems will become increasingly fundamental in future conflicts, where image-based observation technologies are essential for target confirmation and operational precision is critical to combat success.

4.3. Laser technologies and the increased precision of electro-optical systems

Laser technologies have revolutionized electro-optical systems, providing advanced capabilities to enhance the accuracy of fire control operations. The use of lasers in these systems enables detection, tracking, and engagement of targets with unprecedented precision [1]. In recent years, new laser developments have been incorporated into electro-optical systems, significantly improving target aiming and designation capabilities and thus increasing performance in combat situations. This is especially relevant in the naval domain, where fire control systems rely heavily on precision to ensure operational effectiveness. These advances allow operators to acquire targets faster and with greater accuracy, increasing the probability of success in combat scenarios.

4.4. The use of electro-optical systems in target tracking

Accurate target tracking is essential for the effectiveness of fire control systems, particularly in maritime environments where target speed and dynamic sea conditions can complicate operations. Electro-optical systems have proven to be indispensable tools for target tracking, improving both accuracy and acquisition speed. These systems enable operators to track targets in real time, adjusting weapon fire according to target movement [21].

The integration of electro-optical systems into Remote Weapon Stations (RWS) aboard naval platforms has made it possible to overcome the challenges posed by adverse maritime conditions. Through the use of stabilization technologies and advanced fire-prediction algorithms, electro-optical systems can effectively track targets even while the vessel is in motion. This capability is vital for enhancing weapon system effectiveness, optimizing ammunition use, and ensuring that targets are accurately engaged minimizing the risk of collateral damage.

4.5. Challenges in image delay prediction and compensation

One of the most significant challenges in electro-optical systems is the prediction and compensation of image delays. Optronic imaging systems, particularly those operating in dynamic environments such as the sea, often experience latency in the transmission of visual information, regardless of whether the transfer medium is analog or digital [20]. These delays can affect an operator's ability to track and engage targets accurately. Consequently, advanced algorithms and technologies have been developed to predict target movement and compensate for such delays, ensuring that the fire control system operates effectively and can always anticipate the future position of targets of interest, allowing RWS platforms to guarantee accurate impact on the target.

4.6. Stabilization of electro-optical systems at sea

Image stabilization is a critical aspect of electro-optical systems on naval platforms. The constant motion of the vessel, caused by sea conditions, can hinder the system's ability to maintain precise target tracking. Without proper stabilization, the captured images may appear blurred or distorted, compromising target designation and fire control accuracy within the RWS.

To mitigate these effects, modern image stabilization systems employ advanced gyroscopes and motion-compensation software. These technologies allow operators to maintain a clear and stable view of the target even in rough sea conditions. Effective stabilization is essential to ensure that weapon systems operate with maximum accuracy, thereby increasing the overall effectiveness of naval operations [12].

4.7. Artificial intelligence in target detection and classification

A growing trend in electro-optical systems is the use of artificial intelligence (AI) to enhance target detection and classification. AI algorithms can analyze vast amounts of data in real time, enabling more efficient identification and prioritization of threats. This is particularly useful in complex environments where multiple threats may appear simultaneously.

AI also helps reduce the cognitive workload of operators by automating the processes of target detection and classification. Through the use of machine learning algorithms, these systems can improve their ability to identify patterns and predict enemy behavior, providing a significant advantage in combat [9]. In the case of the Colombian Navy's coastal missions, the proper application of AI-based image processing can support all operations involving electro-optical systems installed on RWS platforms, such as counter-narcotics efforts, anti-piracy operations, illegal fishing control, smuggling prevention, and especially search and rescue missions at sea.

4.8. Countermeasures to protect electro-optical systems

Given the importance of these systems, it is crucial to implement countermeasures to protect electro-optical equipment from potential vulnerabilities. As these systems become increasingly vital for weapon control, they also become potential targets for enemy interference. Countermeasures such as masking and electronic jamming are essential to ensure that electro-optical systems continue to function effectively, even in hostile environments [14].

5. Socioeconomic effects of investment in R&D&I for electro-optical systems: job creation, public policy, technological independence, and competitiveness in the global market

5.1. The influence of public policy on R&D&I investment

Incorporating cutting-edge technological developments into national defense policies is essential for Latin American developing countries to close the knowledge gap with more advanced nations. By integrating technologies such as artificial intelligence, cyber defense systems, electro-optical development, and robotics, these countries not only enhance their defense capabilities but also strengthen their local technology industries, fostering innovation and economic growth. This strategy promotes greater technological independence and reduces reliance on foreign suppliers, thereby reinforcing national sovereignty. Moreover, investment in defense-related technology yields cross-sector benefits in areas such as education and industry, driving development and positioning these nations on the global innovation map [18].

African and Arab countries have leveraged current oil revenues to boost investment in research, development, and innovation (R&D&I), recognizing that dependence on hydrocarbons is unsustainable in the long term. They have allocated oil-derived funds to strengthen emerging technological sectors such as artificial intelligence, renewable energy, biotechnology, and optronic system development. This approach aims to ensure future self-sufficiency and independence by diversifying their economies and preparing for a post-oil world. Through investment in R&D&I, these countries are laying the foundation for a transition toward more resilient economies that are less dependent on natural resources [3].

5.2. Examples of investment in R&D&I for defense, self-sufficiency, and economic diversification

Since 2005, China has significantly increased its defense investment, reaching a budget of USD 232 billion in 2024. This growth is driven by the need to modernize its armed forces, strengthen its geopolitical position, and respond to emerging security challenges. However, maintaining such exponential growth could be unsustainable in the long term if not supported by complementary strategies involving public policy, industrial development, and, most importantly, strong investment in research, development, and innovation (R&D&I). By integrating these elements, China not only ensures a technologically advanced defense sector but also promotes self-sufficiency and economic diversification, mitigating the financial and strategic risks associated with its increasing defense expenditure [6].

Indonesia has been a success story over the past decade, having embraced the challenge of investing in defense related research, development, and innovation, thereby avoiding dependence on foreign suppliers. Following the quintuple helix model, which integrates government, industry, academia, civil society, and the armed forces, Indonesia has strengthened its technological and military capacity. Drawing inspiration from countries such as India and Brazil, it has promoted collaboration among these sectors to generate local solutions. This strategy has allowed Indonesia to develop its defense industry, create jobs, and move toward self-sufficiency ensuring greater national security and positioning itself as a regional benchmark in Southeast Asia [23].

Russia, thanks to its advanced technological developments and sustained defense investments, has demonstrated the ability to sustain a prolonged war, such as the invasion of Ukraine, without relying on other countries. In 2023, Russia allocated 25% of its Gross Domestic Product (GDP) to defense, and by 2024, this investment is expected to increase to 40%. This expansion will proportionally boost research and development funding, further strengthening its military and technological capabilities. Russia has prioritized key areas such as artificial intelligence, electro-optical system development, robotics, and cyber defense systems, ensuring strategic self-sufficiency. Comparative analyses of economic investment show that Russia is among the world's top five countries leading in science and technology investment for defense, reinforcing its capacity to sustain long-term conflicts [2].

Israel is one of the countries that invests most heavily in research and development (R&D) for defense, surpassing many Asian and European nations. This public policy of defense-oriented investment not only enhances national security but also generates a cycle of economic growth. The investment drives industrial production lines, creates specialized jobs, and fosters collaboration with academic institutions. This approach strengthens technological innovation, which in turn benefits both the military and civilian industries, boosting

Israel's international competitiveness. Thus, the R&D investment strategy has become a key pillar for the country's economic growth and long-term stability [16].

5.3. Technological trends in electro-optical systems

A study conducted in Portugal, focused on the manufacturing of high-quality electro-optical systems supported by production control software, serves as a clear example of the global trend toward investing in advanced technologies. This approach not only optimizes manufacturing processes but also ensures precision and efficiency in the production of critical systems. Countries such as Portugal are adopting these technologies to enhance their competitiveness in strategic sectors, reflecting the growing global interest in technological innovations that strengthen industry and reduce external dependence [19].

A report published by Site-Direct-Research And Develop (SDRD) confirmed that, after 20 years of design and development, electro-optical systems have become one of the most effective solutions in the military field. These systems provide unprecedented precision and surveillance capabilities, serving as a crucial complement to defense systems across air, land, and sea domains. Their integration into military platforms enhances threat detection and increases operational effectiveness, making them indispensable tools for modern armed forces by boosting their responsiveness in complex and dynamic environments [7].

6. Conclusions

Designing, developing, and innovating in electro-optical technologies over the past two decades has proven to generate a key competitive advantage in the global defense and security arena. Military applications employing these technologies have grown significantly due to their detection, recognition, and identification capabilities under multiple conditions and across various operational domains. Defense companies are increasingly innovating to offer versatile, modular, and high-precision systems, while the industry has also incorporated these dual-use technologies into production processes to enhance efficiency and quality.

Colombia, having already developed Remote Weapon Stations (RWS), must now focus on complementing its technological capacity with the design and development of its own electro-optical systems. This will not only ensure technological independence but also enable self-sufficiency in the maintenance and improvement of its naval RWS platforms, aligning with international standards.

Producing electro-optical systems in Colombia would foster the creation of a domestic industry, generating employment and self-sustainability in the defense sector. Moreover, it would allow these technologies to be leveraged in dual-use civilian applications and improve the efficiency of equipment maintenance and support, thereby strengthening both national defense capability and the economy. A current example of the use of electro-optical systems is the Russia–Ukraine war, particularly in challenging environments. The ability of these systems to provide detailed imagery has enabled greater precision in target acquisition and engagement, optimizing artillery and missile operations. This underscores their value in modern military operations, where visual observation is key to tactical success.

Electro-optical systems continue to evolve through the incorporation of technologies such as artificial intelligence and cybersecurity. These innovations enhance automatic threat detection and classification, increase operational efficiency, and reduce the cognitive workload on operators. Additionally, resilience against vulnerabilities and countermeasures is essential to protect these systems from external interference, ensuring operational reliability in hostile environments and improving battlefield effectiveness.

Despite advances in electro-optical systems, naval platforms still face significant challenges, such as stabilization under adverse maritime conditions, real-time image transmission without delay, and the reduction of data-processing latency. Addressing these issues is essential to maximize the effectiveness of the Remote Weapon Stations (RWS) developed in Colombia, ensuring optimal performance at sea and improving response capability against threats.

Public policies that promote research, development, and innovation (R&D&I) strengthen a nation's ability to achieve technological progress. This approach enables the integration of cutting-edge technologies into key sectors such as defense, enhancing technological independence and fostering global competitiveness. It also stimulates economic growth by creating new opportunities in science and technology, allowing countries to close the gap with more developed nations and eventually complement their industrial and productive sectors with dual-use technologies initially driven by defense advancements.

Countries that allocate a significant proportion of their Gross Domestic Product (GDP) to R&D&I, particularly in defense, have achieved technological and economic self-sufficiency. Examples such as the United States, China, India, Russia, Israel, and, to a lesser extent, Indonesia and Brazil, demonstrate how sustained investment in these areas has led to the development of indigenous capabilities, reduced external dependence, and ensured long-term stability while strengthening their geopolitical and military positions.

The development of indigenous electro-optical systems in Colombia could yield multiple social and economic benefits. This initiative would promote the creation of specialized employment, enhance technological independence, and position the country as a competitive player in the global market. Furthermore, it would foster local capability-building, reduce dependence on imported technology, and contribute to national security through systems specifically tailored to Colombia's operational needs.

Author Contributions: **Cristian Jiménez:** Conceptualization, Methodology, Software, Visualization, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Supervision, Project administration, Funding acquisition. **Oscar Olaya:** Software, Visualization, Validation, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Project administration. **Mervín Sosa:** Investigation, Resources, Data curation, Writing – review & editing, Supervision, Project administration. **Diego Guevara:** Software, Visualization, Investigation, Resources, Writing – original draft.
All authors have read and agreed to the published version of the manuscript. Refer to the taxonomía CRediT for term explanations. Authorship should be limited to those who have contributed substantially to the work reported.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable, since the present study does not involvehuman personnel or animals.

Informed Consent Statement: This study is limited to the use of technological resources, so nohuman 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.

References

1. Abdelhakim, M. M., Khalil, A. A. I., Salah, A., and Alshershby, M. (2024). Exploring the impact of high-power infrared lasers on electro-optical systems performance: A field study with different wavelengths. *Infrared Physics & Technology*, 139:105348.
2. Danielyan, G. (2023). Technological challenges reshaping the defense industry and their impact on economic growth. *Scientific Artsakh*, 4(19):167–175.
3. Douch, M. (2024). Fdi, defense spending, and economic prosperity. Technical report, Political Science and Economics Department, Royal Military College, Kingston, Ontario, Canada.
4. Driggers, R. G., Friedman, M. H., Devitt, J., Furxhi, O., and Singh, A. (2022). *Introduction to Infrared and Electro-Optical Systems, Third Edition*. Artech House, United States.
5. Duczynski, G., Bachmann, S. D., Smith, M., and Knight, C. (2023). Operational and strategic progress in ukraine: Identifying the condition changes. Technical report, ECCO Insight.
6. Fravel, M. T., J., G. G., and E., H. (2024). Estimating china's defense spending: How to get it wrong (and right). Technical report.
7. Guss, P. (2022). Site-directed research & development annual report overview fy 2022. Technical report, U.S. Department of Energy.
8. Hashagen, J. (2014). Swir applications and challenges: A primer. *Photonics Spectra*.
9. Idakwo, M. A., Yoro, R. E., Achimugu, P., and Achimugu, O. (2024). An improved weapons detection and classification system. *Journal of Network and Innovative Computing*, 12:1–1.
10. Intelligence, M. (2023). Sea-based military electro-optical and infrared systems market. Technical report, Mordor Intelligence.
11. Jensen, M. (2020). Remote weapon station market scenario, outlook, size, trend, and. *Daily Herald*.

12. Lan, L., Hua, F., Fang, F., and Jiang, W. (2024). Active compensation technology for the target measurement error of two-axis electro-optical measurement equipment. *Sensors*, 24(4):1133.
13. Lee, S. Y., Lin, J. F., and Lo, Y. L. (2005). Measurements of phase retardation and principal axis angle using an electro-optic modulated mach–zehnder interferometer. *Optics and Lasers in Engineering*, 43(6):704–720.
14. Man, Y., Li, M., and Gerdes, R. (2024). Remote perception attacks against camera-based object recognition systems and countermeasures. *ACM Transactions on Cyber-Physical Systems*, 8(2):Article 14.
15. Markets and Markets (2020). Remote weapon stations market. Technical report, Markets and Markets.
16. Melzer, Y. and Kimhi, A. (2024). Employment in israeli high-tech: Past, present, and future. Technical report, Shoresh Institute.
17. North Atlantic Treaty Organization (1995). Nato standardization agreement (stanag) 4347: Standardization agreement for communication systems. Technical report, North Atlantic Treaty Organization, Brussels.
18. Núñez Brenis, R. C. (2024). Defensa, a la vanguardia de la ciencia y tecnología / defense, at the forefront of science and technology. Technical report, Centro de Altos Estudios Nacionales.
19. Sampaio, M., Lima, A., Fernandes, A., Silva, C., Carneiro, V. H., and Pontes, A. J. (2023). Design and development of an automatic optical inspection (aoi) system support based on digital manufacturing. In *Procedia CIRP*, volume 119, pages 15–20.
20. Shen, C., Wen, Z., Zhu, W., Fan, D., Chen, Y., and Zhang, Z. (2023). Prediction and control of small deviation in the time-delay of the image tracker in an intelligent electro-optical detection system. *Actuators*, 12(7):296.
21. Shen, C., Wen, Z., Zhu, W., Fan, D., and Ling, M. (2024). Optimizing controls to track moving targets in an intelligent electro-optical detection system. *Axioms*, 13(2):113.
22. Sjaardema, A. B., Smith, C. D., and Jansen, E. F. (2015). History and evolution of the johnson criteria. *Journal of Theoretical Psychology*, 35(2):115–132.
23. Surahman, I., N., P. I., and K., A. M. (2024). Independence of the indonesian defense industry and challenges in defense budget allocation. *International Journal of Humanities Education and Social Sciences (IJHESS)*, 3(4):1752–1764.

Authors' Biography

Cristian Jiménez Barrera Electronic Engineer with a specialization in Industrial Automation and Defense Technologies, and a Master's degree in Defense Technologies. He is an expert in automation systems, process control, and weapon system development. He currently serves as the Director of the Naval Technological Development Center (CEDNAV) and is a leading figure in research and technological innovation for the Colombian Navy.

Oscar Eduardo Olaya Vera Electronic Engineer with a specialization in Instrumentation and Industrial Control, holds a Master's degree in Project Management and Innovation, and is currently pursuing a Ph.D. in Engineering. He is an expert in automation and bioengineering, a researcher at the Naval Technological Development Center (CEDNAV), and Head of the Weapon Systems Program.

Mervín Jesús Sosa Borrero Systems Engineer currently pursuing a Master's degree in Engineering with an emphasis on Systems and Computing. He is an expert in systems management, telecommunications networks, technological infrastructure, and information technology (IT) projects. He is also a researcher at the Naval Technological Development Center (CEDNAV) and Head of the Command and Control Systems Program.

Diego Alberto Guevara Amaya Electronics Technologist and Control Engineer currently pursuing a Master's degree in Engineering. He serves as a researcher at the Naval Technological Development Center (CEDNAV) and Research Manager of the Command and Control Program. He has experience in the construction and maintenance of remotely operated weapon stations (RWS), operation, maintenance, and calibration of missiles and torpedoes, as well as in metrology, electronic component assembly, and the application of artificial intelligence in technological and defense systems.