Integration of Big Data and Artificial Intelligence Technologies Into Modern Artillery Systems

Інтеграція технологій великих даних та штучного інтелекту в сучасні артилерійські системи

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Purpose. To systematize the principal directions for integrating big data and artificial intelligence technologies into modern artillery systems and to assess their potential impact on the speed, accuracy, resilience, and decision-making processes of artillery operations, based on documented international experience.

Method: The study employs a structured qualitative review and comparative analytical approach. Academic literature, official military documents, materials published by international organizations, and documented examples of contemporary technological applications were analyzed according to predefined functional criteria.

Theoretical implications. The study contributes to the theoretical understanding of AI and big data integration in artillery systems by conceptualizing their application as a multidimensional transformation process rather than solely as weapon automation. It highlights the interconnected roles of data management, sensor-based information processing, decision support, fire control, technical sustainment, human oversight, and accountability.

Practical implications. The findings provide a functional basis for assessing and developing AI-enabled artillery systems, particularly in relation to data processing, sensor integration, decision support, fire control, maintenance, and logistics. The study also highlights the importance of data quality, cybersecurity, explainability, human oversight, and legal and ethical frameworks for the reliable implementation of such systems.

Value. The value of the study lies in its systematic synthesis of documented international experience and its identification of the principal functional areas in which big data and AI can be integrated into modern artillery systems. It provides a structured perspective for understanding both the potential benefits and the technological, organizational, and governance requirements associated with such integration.

Paper type. Research paper.

Мета дослідження. Систематизувати основні напрями інтеграції технологій великих даних і штучного інтелекту в сучасні артилерійські системи та оцінити їхній потенційний вплив на швидкість, точність, стійкість і процеси прийняття рішень під час ведення артилерійських операцій на основі документованого міжнародного досвіду.

Метод дослідження. У дослідженні застосовано структурований якісний огляд і порівняльно-аналітичний підхід. Наукову літературу, офіційні військові документи, матеріали, опубліковані міжнародними організаціями, а також документовані приклади сучасного застосування технологій проаналізовано відповідно до заздалегідь визначених функціональних критеріїв.

Теоретична цінність дослідження. Дослідження поглиблює теоретичне розуміння інтеграції штучного інтелекту та великих даних в артилерійські системи, концептуалізуючи їх застосування як багатовимірний процес трансформації, а не лише як автоматизацію озброєння. Висвітлено взаємопов'язані ролі управління даними, оброблення інформації, отриманої від сенсорів, підтримки прийняття рішень, управління вогнем, технічного забезпечення, людського контролю та підзвітності.

Практична цінність дослідження. Отримані результати формують функціональну основу для оцінювання та розроблення артилерійських систем із використанням штучного інтелекту, зокрема щодо оброблення даних, інтеграції сенсорів, підтримки прийняття рішень, управління вогнем, технічного обслуговування та логістичного забезпечення. У дослідженні також підкреслено важливість якості даних, кібербезпеки, пояснюваності рішень, людського контролю, а також правових та етичних засад для надійного впровадження таких систем.

Цінність дослідження. Цінність дослідження полягає в систематичному узагальненні документованого міжнародного досвіду та визначенні основних функціональних напрямів, у межах яких великі дані та штучний інтелект можуть бути інтегровані в сучасні артилерійські системи. Запропоновано структурований підхід до розуміння як потенційних переваг такої інтеграції, так і пов'язаних із нею технологічних, організаційних вимог та вимог до управління.

Тип статті. Дослідницька стаття.

Key words: Big Data; Artificial İntelligence; Artillery Systems; Machine Learning; Decision Support; Real-Time Data Processing; Fire Control; Predictive Maintenance; Human Oversight; Cybersecurity.

Ключові слова: великі дані; штучний інтелект; артилерійські системи; машинне навчання; підтримка прийняття рішень; оброблення даних у реальному часі; управління вогнем; прогнозне технічне обслуговування; людський контроль; кібербезпека.

Introduction

The modern battlespace differs significantly from military operations of previous periods, which were based on relatively limited information flows. Unmanned aerial vehicles (UAVs), satellite systems, radars, electro-optical systems, ground-based sensors, and other intelligence sources enable the continuous generation of battlefield information in diverse formats. The timely collection, transmission, processing, and integration of this information into decision-making processes have become key components of the effectiveness of modern military systems.

This transformation is particularly significant for artillery systems. The effective employment of artillery depends not only on the technical characteristics of weapon platforms but also on the speed and reliability of interaction among the stages of intelligence acquisition, target identification, data processing, decision-making, and fire control. Consequently, modern artillery systems are increasingly being integrated with digital communications, sensor networks, automated data-processing capabilities, and decision-support technologies.

Big data constitutes the information foundation of this transformation. Since large volumes of data generated at high velocity and in diverse formats are difficult to process with conventional methods, advanced analytical and computational tools are required to transform them into actionable information. Technologies such as artificial intelligence (AI), machine learning, and deep learning create new opportunities for pattern identification, classification, prediction, and decision support in large datasets (Laney, 2001; LeCun et al., 2015; McCarthy, 2007).

The integration of artificial intelligence into military systems is not limited to the automation of weapons. Contemporary approaches encompass a broad range of functions, including data processing, enhanced situational awareness, decision support, maintenance, logistics, and improved human-machine interaction. The multifaceted nature of AI applications in the military domain, therefore, requires that the technology be considered not merely as an individual algorithm but as an integral component of a broader digital ecosystem (Anduril Industries, 2025; Mueller, 2025).

From the perspective of artillery systems, one of the particularly important areas is the acceleration of the "sensor-to-decision-to-fire" chain. The integration of data received from multiple sensors within a unified information environment, combined with automated analytical tools, has the potential to reduce the time required for decision-making. Projects implemented in recent years in countries such as the United States, the United Kingdom, Ukraine, and Israel to digitalize artillery and fire-control systems provide practical examples of this trend (Anduril Industries, 2025; BAE Systems, 2026; Defense Express, 2023; Department of the Army, 2020; Mueller, 2025).

At the same time, the integration of technology into military systems does not automatically translate into greater combat effectiveness. The performance of AI systems depends on the quality of data, the reliability of sensors, communications infrastructure, cybersecurity, and the role of human operators in the decision-making process. NATO's principles for responsible artificial intelligence likewise identify lawfulness, accountability, explainability, reliability, governability, and bias mitigation as key elements for the trustworthy implementation of AI systems (NATO, 2021).

At the same time, it is necessary to distinguish between the concepts of automation and autonomy in artillery systems. A system that automatically processes information or assists in the preparation of a firing solution should not necessarily be regarded as an autonomous weapon system. The stage and degree to which a human operator participates in the decision-making process are critical to determining the actual level of system autonomy. This issue requires particular attention from both technical and international humanitarian law perspectives (International Committee of the Red Cross, 2026; NATO, 2021; United Nations Office for Disarmament Affairs, 2025).

Thus, although the existing literature extensively examines individual military applications of artificial intelligence and big data, the functional domains in which these technologies are integrated into artillery systems have yet to be comprehensively systematized within a unified framework. The comparative analysis of contemporary examples from different countries also remains an area requiring further investigation.

The objective of this study is to systematize the principal directions for integrating big data and artificial intelligence technologies into modern artillery systems and to assess their potential impact on the speed, accuracy, resilience, and decision-making processes of artillery operations based on documented international experience.

The principal scientific contribution of the study is the functional systematization of the integration of artificial intelligence and big data into artillery systems across the following areas:

intelligence and data processing;

target detection and classification;

decision support;

fire control and automation;

maintenance and logistics;

cybersecurity and human oversight.

This approach enables the study to go beyond merely describing individual technological applications and to provide a comparative perspective on how these technologies are interconnected across the different functional stages of an artillery system.

Literature Review

The rapid growth in the volume, diversity, and processing speed of information in modern military operations has increased the importance of data-driven technologies in decision-making processes. In particular, big data analytics, machine learning, and artificial intelligence technologies have become important tools for processing information from multiple data sources, developing situational awareness, and supporting decision-making. Recent academic and institutional sources have examined data-driven technologies in military decision support, predictive maintenance, and digital command-and-control processes (Anduril Industries, 2025; Dalzochio et al., 2023).

The Concept of Big Data

Big data refers to large datasets that are difficult to manage efficiently with conventional data-processing tools due to their volume, high generation rate, and diverse formats. The key characteristics of this concept have traditionally been defined as volume, velocity, and variety (Laney, 2001).

The sources of big data in military systems are highly diverse. Video and imagery data obtained from UAVs, radar signals, satellite imagery, electronic and acoustic sensor data, geographic information, and other data collected through operational systems contribute to the formation of a unified information environment. From the perspective of effective decision-making, the importance of such data lies not only in its collection but also in its timely integration and analysis.

From this perspective, big data should be regarded in artillery systems not merely as a standalone technology, but rather as a data infrastructure that integrates multiple sensors and information sources. Its primary function is to provide the data foundation required for the operation of artificial intelligence and analytical algorithms.

Artificial Intelligence, Machine Learning, and Deep Learning

Artificial intelligence (AI) is a broad set of technologies and methods that enable computer systems to perform functions commonly associated with human intelligence, including perception, learning, pattern recognition, prediction, and decision-making. In this context, artificial intelligence represents the broader concept, while machine learning constitutes one of its principal methodological approaches.

Machine learning (ML) enables systems to identify patterns in data and generate predictions or classifications based on those patterns without requiring all operational rules to be explicitly programmed in advance. In military applications, ML can be used for tasks such as analyzing large volumes of sensor data, object classification, anomaly detection, and decision support.

Deep learning (DL), in turn, is a machine learning approach based on multilayer artificial neural networks. This method is particularly effective for the automatic extraction of features from images, video, audio, and other complex forms of data. LeCun et al. (2015) demonstrated that deep learning can learn abstract representations of data at multiple levels through successive processing layers, achieving significant results in tasks such as image and object recognition.

Accordingly, a hierarchical relationship can be established among these concepts:

Big data – the data foundation and information environment;

Artificial intelligence – the framework for intelligent processing and decision-making;

Machine learning – the learning of patterns from data;

Deep learning – the automated analysis of complex and high-dimensional data.

The Role of Artificial Intelligence in Military Decision Support

One of the principal advantages of artificial intelligence in military environments is its ability to assist in processing large volumes of information from diverse sources without exceeding the physical and cognitive capacities of human operators. Data-driven military technologies can provide decision support for situational awareness development, data analysis, and evaluation of different courses of action (Anduril Industries, 2025).

Within this approach, the role of artificial intelligence can be understood not primarily as an automatic replacement for human decision-making, but rather as a means of rapidly analyzing information and presenting relevant information to support the decision-making process. The effective implementation of AI-based systems depends not only on technical infrastructure but also on the development of appropriate digital and analytical competencies among military personnel. The integration of emerging technologies into military training can enable personnel to use AI-based decision-support systems appropriately and responsibly (Mammadzada, 2025). This distinction is particularly important in military systems because automated data processing, AI-assisted decision support, and fully autonomous decision-making are not equivalent concepts.

Accordingly, this study adopts the following distinctions when assessing the level of automation of AI-enabled artillery systems:

Automated system – performs specific operations without human intervention based on predefined rules;

AI-assisted system – uses artificial intelligence to analyze data and assist the operator in making decisions;

Decision-support system – provides alternatives or recommendations, while the final decision is made by a human;

Human-in-the-loop – a human directly participates in the decision-making process during system operation;

Human-on-the-loop – the system performs certain functions automatically while a human monitors and supervises the process;

An autonomous system – capable of performing certain functions without continuous human intervention.

This terminological distinction is particularly important because the use of artificial intelligence to calculate firing solutions or process sensor data does not, by itself, mean that the system constitutes an autonomous weapon system.

Theoretical Integration Model for Artillery Systems

Based on the literature analysis, the integration of big data and artificial intelligence into artillery systems can be grouped into six functional areas:

1. Intelligence and data processing – collection, integration, and initial processing of data received from UAVs, radars, satellites, and other sensors;

2. Target-data analysis – detection and classification of objects from imagery and other sensor data, and the development of situational awareness;

3. Decision support and fire control – provision of decision support to commanders and operators based on available information;

4. Weapon-system automation – automation of loading, aiming, and other functions;

5. Predictive maintenance and logistics – assessment of equipment condition based on sensor data, prediction of potential failures, and planning of logistical requirements;

6. Cybersecurity, reliability, and human oversight – protection of data, resilience against cyber threats, system reliability, and maintenance of appropriate human control.

This approach enables different countries and technological systems to be compared according to common functional criteria rather than merely presented descriptively.

Materials and Methods

This study was conducted using a qualitative structured narrative review and a comparative analytical approach. The primary objectives of the study are to systematize the principal directions for integrating big data and artificial intelligence technologies into modern artillery systems, to compare implementation practices across countries, and to assess the potential impact of these technologies on the speed, accuracy, resilience, and decision-making processes in artillery operations. The study is not based on experimental procedures or statistical measurements; rather, it relies on the structured analysis of existing scholarly and documentary evidence. Accordingly, the findings are based on a comparative interpretation of the evidence presented in the available sources.

Three main categories of sources were prioritized during the source selection process:

peer-reviewed academic publications;

documents and materials issued by official military and governmental institutions;

reliable institutional and corporate sources documenting the practical implementation of relevant technologies.

The review was not designed as a systematic review in the PRISMA sense; rather, sources were purposively selected according to their relevance, reliability, institutional character, and documentation of specific technological applications.

The academic literature was used to identify conceptual and technical areas, including artificial intelligence, machine and deep learning, big data analytics, real-time data processing, and predictive maintenance (Dalzochio et al., 2023; Laney, 2001; LeCun et al., 2015; McCarthy, 2007; Scott et al., 2022; Zhuang et al., 2024). Official military and institutional sources were reviewed to verify information on artillery command-and-control systems, digital fire control, artificial intelligence strategies, and autonomous weapon systems (Anduril Industries, 2025; BAE Systems, 2026; Department of the Army, 2020; International Committee of the Red Cross, 2026; Mueller, 2025; NATO, 2021; United Nations Office for Disarmament Affairs, 2025).

The principal criteria for source selection were relevance to the research topic, source reliability, primary or institutional character, timeliness of the information, and the documentation of a specific technological application. Particular emphasis was placed on sources published or updated between 2021 and 2026. At the same time, earlier foundational works establishing the theoretical foundations of big data, artificial intelligence, and deep learning were also taken into consideration (Laney, 2001; LeCun et al., 2015; McCarthy, 2007). This approach made it possible to examine both recent developments in military technologies and their underlying theoretical and technical foundations within a common analytical framework.

For the international comparative analysis, the cases of the United States, Ukraine, the United Kingdom, and Israel were selected. These countries were chosen because they have documented applications involving the digitalization of modern artillery systems, integration of sensor data, AI-based decision support, automated fire control, and maintenance capabilities. The analysis did not compare the overall military capabilities of these countries; rather, it focused on the extent to which artificial intelligence and big data have been integrated into the operational capabilities of their artillery systems.

In the comparative analysis, the systems were evaluated according to the following functional criteria:

integration of data sources and sensors;
target detection and classification;
decision support for fire control;
level of automation;
role of human oversight.

This functional approach enabled comparison of different technological systems within a unified framework and made it possible to determine not only their individual technical characteristics but also their position within the broader information and decision-making chain of artillery operations.

During the analytical stage of the study, the collected information was systematized through functional-thematic grouping and comparative synthesis. The collected materials were organized into six principal areas:

intelligence and data processing;
target detection and classification;
fire control and decision support;
automation of weapon systems;
predictive maintenance and logistics;
cybersecurity, reliability, and human oversight.

This framework constitutes the principal analytical approach of the study and enables international practices to be presented not merely descriptively, but in a functionally systematized and comparative manner.

Results

The results of the structured literature review and comparative analysis indicate that the integration of big data and artificial intelligence technologies into modern artillery systems is primarily concentrated in six functional areas:

data collection and processing;
target-data analysis;
decision support and fire control;
system automation;
predictive maintenance and logistics;
cybersecurity, reliability, and human oversight.

These areas are not fully independent of one another; rather, they constitute interconnected elements of an integrated digital battlespace management ecosystem.

Functional Application Areas of Big Data and Artificial Intelligence Technologies in Artillery Systems

The effectiveness of modern artillery systems depends not only on the technical capabilities of weapon platforms but also on how rapidly and reliably large volumes of battlefield data can be processed. Unmanned aerial vehicles, radars, satellite systems, electro-optical systems, and other sensors continuously generate data in diverse formats. Big data technologies enable the collection, storage, and processing of this information, thereby supporting the integration of multiple information sources within a unified digital environment (Laney, 2001).

Artificial intelligence, machine learning, and deep learning technologies, in turn, enable the faster analysis of collected data and the identification of complex patterns. In particular, deep learning algorithms have significant potential for tasks such as automatic feature extraction from large datasets and image and object recognition (LeCun et al., 2015). From the perspective of artillery systems, these capabilities are particularly relevant to analyzing information from multiple sensors, generating target-related information, and providing analytical support to decision-makers.

The application of these technologies in artillery systems can be grouped into the following principal functional areas:

Collection and processing of intelligence data. The integration of imagery, radar, thermal, and other sensor data within a unified system can enable operators to develop a more comprehensive situational awareness. AI-based algorithms can support the identification of potentially significant objects within large volumes of data and the prioritization of information.

Target detection, classification, and decision support. Artificial intelligence systems can analyze sensor and imagery data to assist in identifying potential objects. An important consideration, however, is that automated detection and classification should not necessarily be equated with independent target selection or firing decisions. Such systems can also serve as AI-assisted decision-support tools, providing human operators with relevant information and analytical support. This distinction helps prevent AI-enabled systems from being automatically characterized as “autonomous weapons.”

Fire control and digital command-and-control systems. A key objective of contemporary approaches is to accelerate information exchange among different sensors, command posts, and firing assets. The implementation of the AXS system during the Ivy Sting exercises conducted under the U.S. Army’s NGC2 initiative provides a practical example of integrating multiple information sources and firing assets within a unified digital environment. According to the available information, the system enabled shorter processing times for preparing and transmitting fire missions compared with previous approaches (Anduril Industries, 2025).

Weapon-system automation. In this area, it is important to maintain a clear terminological distinction among automated, AI-assisted, and autonomous systems. An automated system can perform specific technical and computational operations without requiring human intervention at every stage. An AI-assisted system provides recommendations and analytical information to the decision-maker. An autonomous system, by contrast, may perform certain functions with a higher degree of independence. Therefore, the automatic calculation of firing solutions or the automation of technical processes does not, in itself, mean that a system constitutes an autonomous weapon operating beyond human oversight.

Predictive maintenance and logistics optimization. Big data analytics can help anticipate maintenance needs by analyzing data on equipment condition, usage intensity, and historical failures. The same approach can also be applied to logistics and ammunition inventory management (Dalzochio et al., 2023; Scott et al., 2022).

Thus, the integration of big data and artificial intelligence technologies into artillery systems is not limited to automating the firing process. Rather, their application creates an interconnected functional chain encompassing data collection and processing, generation of target-related information, decision support, digital fire control, maintenance, and logistics. This functional approach facilitates the comparative analysis of international practices and enables a clearer assessment of the technological capabilities of systems implemented in different countries.

Comparative Analysis of International Practices

In recent years, countries such as the United States, the United Kingdom, Ukraine, and Israel have undertaken significant projects to digitize artillery systems and integrate diverse information sources into fire-control processes. A comparison of these practices demonstrates that artificial intelligence and big data technologies are not applied in the same manner across all systems. Some projects primarily focus on integrating sensor data and decision support, while others emphasize target detection and the automation of weapon platforms.

From this perspective, international practices can be compared using functional criteria such as data integration, target data processing, fire control, automation, and human oversight.

The United States

In the United States, the digitalization of artillery systems has primarily focused on integrating data from multiple sensors into a unified digital environment and accelerating fire mission processing. In this regard, the NGC2 (Next Generation Command and Control) initiative is of particular importance. During the Ivy Sting 1 exercises conducted in 2025, the Artillery Execution Suite (AXS) system was used in 26 fire missions involving M777 howitzers, and it was reported that the time required to complete the process from sensor input to execution of a fire mission was reduced to less than one minute (Anduril Industries, 2025).

Another example from the United States is Project Shrike. The system uses artificial intelligence to analyze live imagery obtained from UAVs and supports the detection, identification, and geolocation of potential targets. During a 2025 demonstration, the system was reported to have generated firing solutions, while the final decision remained with a human operator (Mueller, 2025). This characteristic allows Project Shrike to be more appropriately categorized as an "AI-assisted decision-support" approach rather than a fully autonomous system.

Thus, two complementary directions can be observed in the U.S. case: NGC2/AXS focuses on the digitalization of information and command-and-control processes, while Project Shrike focuses on AI-based processing of sensor data and decision support.

Ukraine: IFATDS and Network-Centric Artillery Management

The application of modern artillery systems in Ukraine demonstrates the importance of integrating diverse intelligence and firing assets within a unified information environment. The IFATDS systems provided by the United States support the rapid transmission of information from multiple sources, including counter-battery radars, unmanned aerial vehicles, and other intelligence assets, to artillery units. This approach enhances situational awareness among artillery units and accelerates information exchange across different weapon systems (Defense Express, 2023).

The United Kingdom

In the United Kingdom, one of the principal directions in the development of artillery systems has been to strengthen digital connectivity among different sensors and firing assets. The Next Generation Indirect Fire Control System (NGIFCS), presented by BAE Systems at the Eurosatory exhibition in June 2026, is designed to enhance speed, accuracy, and networked coordination in contemporary artillery operations. According to the company, the system connects weapon systems to broader sensor and effector networks, thereby enabling more efficient information transmission within the operational environment (BAE Systems, 2026).

Unlike the U.S. examples, the principal feature highlighted in the capabilities presented for NGIFCS is not a specific artificial intelligence function, but rather digital fire control and the integration of diverse information sources within a networked environment. Therefore, this system demonstrates the importance of considering the application of big data and artificial intelligence technologies in artillery within the broader context of digital infrastructure.

Israel

Israel's Ro'em/SIGMA 155 system represents a distinct example of increasing automation within the artillery platform itself. The system is designed to employ modern command-and-control and intelligence information to enable a higher degree of automation in firing processes. Open-source information indicates that a significant portion of the loading, aiming, and firing processes is automated, with the system designed to operate with a reduced crew (Elbit Systems, n.d.).

However, here as well, a clear distinction must be maintained between automation and full autonomy. Even if a system performs certain technical and firing processes automatically, this does not necessarily mean that it operates entirely without human oversight. This distinction is important in evaluating modern military technologies from both terminological and legal perspectives.

Comparative Assessment

The analysis indicates that, across the practices of the countries examined, the integration of artificial intelligence and big data into artillery systems is developing primarily along three distinct but complementary directions: data and sensor integration, AI-assisted decision support, and platform-level automation**.** The comparative assessment of the selected international artillery systems, based on their primary data sources, technological functions, roles in the firing process, and levels of human oversight, is presented in Table 1.

Table 1: Comparative Assessment of Big Data and Artificial Intelligence Integration in Selected Artillery Systems

Country / System	**Primary Data Sources**	**Primary Technological Function**	**Role in the Firing Process**	**Human Oversight**
United States – NGC2/AXS	Sensors, intelligence sources, and digital networks	Data integration and digital command and control	Rapid processing and transmission of fire missions and coordination of their execution	**Human oversight is maintained**
United States – Project Shrike	Live imagery obtained from UAVs and other sensor data	AI-based target detection, identification, and analysis	Decision support for the generation of target information and firing solutions	**The final decision remains with the human operator**
Ukraine – IFATDS	Counter-battery radars, UAVs, and other intelligence assets	Integration of multiple information sources within a unified network	Rapid transmission of intelligence information to artillery units and coordination of firing assets	**Human-controlled decision-making process**
United Kingdom – NGIFCS	Sensors, effectors, and other networked sources	Network-based integration of digital data and fire control	Accelerating information exchange between firing assets and sensors and enhancing digital fire control	**Human oversight is maintained**
Israel – Ro'em/SIGMA 155	C2 systems and intelligence data	High-level platform automation	Automation of a significant portion of loading, aiming, and firing processes	**Operator oversight; not fully autonomous**

Source: developed by the author based on Anduril Industries (2025), BAE Systems (2026), Defense Express (2023), Elbit Systems (n.d.), and Mueller (2025).

The comparison demonstrates that the principal differences among these systems are reflected not only in the technologies employed but also in the degree of human-machine interaction. In systems such as Project Shrike, artificial intelligence primarily provides analytical support to the human operator, while the final decision remains with the human. The NGC2/AXS approach focuses primarily on connecting diverse data sources and systems within a unified digital environment. NGIFCS places greater emphasis on network-based digital fire control. In the Ro'em example, automation is extended more directly to the functional operations of the weapon platform itself.

These differences indicate that the development of modern artillery systems is characterized less by a simple transition to a single model of "fully autonomous artillery" and more by a gradual technological transformation encompassing data digitalization, sensor integration, AI-assisted decision support, fire-control automation, and platform-level automation.

At the same time, the performance indicators for the effectiveness of the systems discussed above are largely based on open-source information from manufacturers, military institutions, and project participants. Therefore, these findings should be interpreted with caution and should not be treated as universal empirical results applicable to all artillery systems. The available evidence primarily demonstrates the potential of these technologies and their capabilities demonstrated under actual training and testing conditions.

From this perspective, international experience shows that the application of artificial intelligence and big data in artillery systems is not limited to the automation of firing processes. Rather, it contributes to the development of a complex digital ecosystem encompassing interconnected areas such as data management, sensor integration, decision support, logistics, and technical maintenance.

Discussion

The analysis demonstrates that integrating big data and artificial intelligence technologies into artillery systems is not a single technological solution but rather a complex process spanning multiple functional levels. The analysis of the literature and international practices indicates that this integration is developing primarily in the areas of data collection and processing, sensor integration, target data generation, decision support, fire control, maintenance, and logistics (Anduril Industries, 2025; Dalzochio et al., 2023; Laney, 2001; LeCun et al., 2015; Scott et al., 2022).

A comparison of international examples demonstrates that the application of artificial intelligence in artillery systems does not necessarily entail a transition toward full autonomy in all cases. Rather, existing systems exhibit varying levels of automation and decision support, retaining human participation in the decision-making process. In this regard, distinguishing between “AI-assisted”, “human-in-the-loop”, and “human-on-the-loop” approaches is important for both technical and legal assessment.

The study's findings also demonstrate that increased technological capabilities do not automatically translate into greater operational effectiveness. The practical utility of a system under real-world conditions depends on factors such as data quality, the reliability of communications infrastructure, sensor accuracy, the representativeness of the data used to train the model, the preparedness of human operators, and organizational integration. Therefore, the integration of artificial intelligence into artillery systems should not be assessed merely as the modernization of software or an individual weapon platform, but rather as the integration of human, technological, informational, and command-and-control processes.

Compared with existing international practices, the principal theoretical contribution of this study lies in systematizing the application of big data and artificial intelligence in artillery systems according to a functional sequence. Within the proposed approach, data collection and processing constitute the initial stage; target data generation and decision support constitute the intermediate stage; and digital fire control and platform-level automation constitute higher levels of technological integration. This model can serve as a conceptual framework for the comparative assessment of existing international examples.

Risks, Challenges, and Limitations of the Study

Alongside the integration of artificial intelligence and big data into artillery systems, a range of technical, informational, legal, and organizational risks may also emerge. In particular, data security and system cyber-resilience are of critical importance. The introduction of erroneous or manipulated data into AI systems can affect the reliability of their analytical outputs. From this perspective, manipulated or unreliable data, degraded sensor inputs, and model reliability problems should be considered important risk categories.

Another important issue concerns the resilience of communications and computing infrastructure. The effective operation of AI-based systems may depend on reliable data exchange, computational resources, and energy availability. Consequently, the ability of systems to operate in a "degraded-mode operation", that is, under conditions of reduced functionality when communications are limited, or data flows are disrupted, is an important operational requirement.

Increasing levels of autonomy also raise significant legal and ethical considerations. In particular, the degree of human oversight in decisions that may result in loss of life, the allocation of responsibility, and compliance with the requirements of international humanitarian law remain important issues (International Committee of the Red Cross, 2026; United Nations Office for Disarmament Affairs, 2025). From this perspective, maintaining human oversight and ensuring the explainability of decisions should be regarded as key components of the reliability of military artificial intelligence systems.

The principal limitation of this study is its qualitative comparative-review design. No experimental testing, independent statistical measurements, or primary data concerning the performance of operational combat systems were available within the scope of the study. Furthermore, some information on international practices is limited to publicly available official documents, corporate materials, and disclosures from military institutions. Consequently, the technological and operational outcomes presented in this article should not be interpreted as universal empirical findings, but rather as capabilities documented or reported in the available open sources.

Recommendations and Directions for Future Research

Based on the analysis, several areas warrant priority to improve the effectiveness of integrating big data and artificial intelligence technologies into artillery systems.

Expanding digital command-and-control and data-exchange capabilities. It is important to enhance the digital command-and-control and information-exchange capabilities of existing artillery systems. The exchange of information among sensors, intelligence assets, and firing systems within a unified digital environment can improve situational awareness and decision support.

Strengthening AI reliability and cyber-resilience. The reliability and cyber-resilience of AI systems should be considered from the earliest stages of their development. This requires particular attention to data quality assurance, continuous model monitoring, anomaly detection, and the ability of systems to operate under conditions of limited communication.

Clearly defining levels of automation and autonomy. Levels of automation and autonomy should be clearly defined, while appropriate levels of human oversight should be maintained at relevant stages. Particularly for high-consequence decisions, it is essential that the human operator retain the ability to evaluate information provided by the system, approve decisions, and, where necessary, interrupt the process.

Developing multidisciplinary expertise. Military research and educational institutions should strengthen multidisciplinary personnel development in artificial intelligence, big data, cybersecurity, and human-machine interaction.

Future research should build upon the functional model identified in this study and conduct more systematic quantitative comparisons. In particular, measurable indicators such as data-processing latency, system availability, target-detection performance, false-positive and false-negative rates, maintenance performance, and the duration of the human-machine decision cycle could provide a basis for future empirical investigations.

Conclusion

This study analyzed the integration of big data and artificial intelligence technologies into modern artillery systems based on the existing academic literature and international practices. The findings demonstrate that the application of these technologies is not limited to the automation of weapon platforms, but encompasses a range of interconnected functions, including data collection, sensor integration, target-data processing, decision support, digital fire control, maintenance, and logistics.

The comparative analysis of international practices demonstrated that the United States, the United Kingdom, Ukraine, and Israel have adopted different technological approaches to the digitalization and automation of artillery systems. In the United States, the digitalization of data and command-and-control systems and AI-assisted decision support are particularly prominent; in Ukraine, the network-based integration of diverse intelligence and firing assets is more pronounced; in the United Kingdom, digital coordination between sensors and effectors represents a key area of development; while in Israel, greater emphasis is placed on platform-level automation. Nevertheless, the application of these technologies does not imply that the systems should be regarded as fully autonomous. In most cases, human decision-making and oversight functions remain integral to the operational process.

The principal scientific contribution of this study is the systematization of the application of big data and artificial intelligence in artillery systems across the following functional areas:

data processing;
target-data generation;
decision support and digital fire control;
platform-level automation;
maintenance and logistics;
cybersecurity, reliability, and human oversight.

This approach provides a conceptual framework that enables different technological solutions to be assessed and compared from a common functional perspective.

At the same time, the study demonstrates that, alongside the technical and organizational benefits of applying artificial intelligence, a number of challenges remain, including data security, cyber resilience, model reliability, data quality, human oversight, and legal accountability. Therefore, the effectiveness of these technologies is determined not solely by their technological capabilities but also by the quality of data infrastructure, human resources, organizational readiness, and the applicable legal framework.

The principal limitation of the study is its qualitative comparative design based on open-source information, without independent experimental or statistical measurements. Accordingly, the findings should be interpreted as a systematic assessment of existing international practices, and no definitive conclusions should be drawn that these technologies will produce identical outcomes under all operational conditions.

Future research may focus on quantitatively comparing performance indicators across AI-enabled artillery systems, assessing human-machine interaction, investigating system cyber-resilience, and developing methodological frameworks for trustworthy AI implementation. Overall, the integration of big data and artificial intelligence technologies into artillery systems represents an important direction in the digital transformation of military technologies.

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Competing interests

The authors declare that they have no competing interests.

Use of Artificial Intelligence

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