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Verification and Control of International Treaty Regulation on Missile-Nuclear Armaments

Vyacheslav Myronenko [1] *

[1] *Center for Military and Strategic Studies of the National Defense University of Ukraine (Ukraine). Candidate of Technical Sciences.*

*** *Corresponding Author,*** e-mail: slavik_kiev@ukr.net

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ABSTRACT

In the context of the weakening of international treaties on missile-nuclear arms control and the rise of asymmetric threats, traditional verification mechanisms have become increasingly ineffective. The study is relevant for scientifically substantiating the transformation of arms control approaches by integrating intelligence tools as a key element to ensure transparency and confidence. The aim of the article is to develop a conceptual model for integrating intelligence support into verification mechanisms for nuclear and missile systems, considering Ukraine's needs and the current state of international legal regimes. The research employs a complex of general scientific and specialized methods, including systems analysis, analytical, comparative-legal, and synthetic approaches. It examines international agreements, including the Treaty on the Non-Proliferation of Nuclear Weapons and bilateral strategic arms agreements, as well as the use of national technical monitoring means, satellite surveillance, open-source intelligence, and electronic intelligence. The analysis demonstrates that existing verification mechanisms are undergoing a structural crisis due to political paralysis and institutional limitations. Intelligent technologies and big data processing have become the primary source of information for compliance assessment. A three-tier integration model is proposed: organizational level (establishment of an International Nuclear Risk Monitoring Center involving Ukraine, NATO, and the IAEA), technological level (automated satellite data processing, electronic intelligence, and AI-based escalation forecasting), and regulatory level (automation of responses to violations, legally binding data exchange protocols). Integrating intelligence support into international arms control mechanisms allows for a transition from declarative and reactive approaches to preventive risk management. This transformation is especially relevant for non-nuclear states participating in collective security mechanisms, such as Ukraine. The proposed model provides a reliable foundation for building technologically oriented, transparent, and legally grounded arms control systems.

KEYWORDS

intelligence support, verification, arms control, missile-nuclear domain, international legal regimes, strategic stability, risk monitoring, automated analysis systems.

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Верифікація та контроль за ракетно-ядерним озброєнням у міжнародно-правових режимах

Вячеслав В. Мироненко [1 *]

[1] *Центр воєнно-стратегічних досліджень Національного університету оборони України (Україна). Канд. техн. наук.*

*** *Автор-кореспондент,*** e-mail: slavik_kiev@ukr.net

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АНОТАЦІЯ

У сучасних умовах ослаблення міжнародних договорів щодо контролю над ракетно-ядерними озброєннями та зростання асиметричних загроз традиційні механізми верифікації стають недостатньо ефективними. Актуальність дослідження полягає у необхідності науково обґрунтувати трансформацію підходів до контролю озброєнь із включенням розвідувальних інструментів як ключового елементу забезпечення прозорості та довіри. Метою статті є розробка концептуальної моделі інтеграції розвідувального забезпечення у механізми верифікації ядерних та ракетних систем з урахуванням потреб України та сучасного стану міжнародно-правових режимів. Для досягнення мети використано комплекс загальнонаукових і спеціальних методів, зокрема системний, аналітичний, порівняльно-правовий та синтетичний підходи. Досліджено міжнародні договори, включно з Договором про нерозповсюдження ядерної зброї та двосторонніми угодами щодо стратегічних наступальних озброєнь, а також практику застосування національних технічних засобів контролю, супутникового спостереження, відкритих джерел інформації та електронної розвідки. Аналіз показав, що існуючі механізми верифікації зазнають структурної кризи через політичний параліч та обмеженість інституційних інструментів. Розвідувальні технології та обробка великих даних стають основним джерелом інформації для оцінки дотримання зобов'язань. Запропоновано трирівневу модель інтеграції: організаційний рівень (створення міжнародного центру моніторингу ядерних ризиків за участю України, НАТО та МАГАТЕ), технологічний рівень (автоматизовані системи обробки супутникових даних, електронна розвідка, штучний інтелект для прогнозування ескалаційних дій), нормативно-правовий рівень (автоматизація реакції на порушення, юридично обов'язкові протоколи обміну даними). Інтеграція розвідувального забезпечення у міжнародні механізми контролю озброєнь дозволяє перейти від декларативних і реактивних підходів до системи превентивного управління ризиками. Така трансформація особливо актуальна для держав, що не мають ядерної зброї, але беруть участь у колективних механізмах безпеки, таких як Україна. Розроблена модель забезпечує надійну основу для побудови технологічно орієнтованих, прозорих та юридично обґрунтованих систем контролю.

КЛЮЧОВІ СЛОВА

розвідувальне забезпечення, верифікація, контроль озброєнь, ракетно-ядерна сфера, міжнародно-правові режими, стратегічна стабільність, моніторинг ризиків, автоматизовані системи аналізу.

1. Introduction

The strengthening of asymmetric threats and the weakening of the treaty framework for nuclear missile arms control necessitate a revision of traditional approaches to verification and ensuring strategic stability. The key problem of modern international legal regimes is the limited ability of existing institutions to provide independent and prompt monitoring of compliance with obligations, especially when one of the parties deliberately evades the implementation of agreements or uses the nuclear factor as an instrument of political pressure. The relevance of the study lies in the need for a scientific justification for the transition to a new verification architecture, in which intelligence tools become not an auxiliary, but a system-forming element of international legal regimes, which is especially important for states that do not possess nuclear weapons, but participate in the formation of collective security mechanisms and seek to strengthen their own subjectivity in the global non-proliferation regime.

2. Literature Review

The issue of integrating intelligence tools into arms control mechanisms has become especially acute after the weakening of key international agreements and the growing role of non-inspection verification methods. Modern research focuses on finding the optimal combination of traditional inspection procedures with modern technologies for collecting and processing information.

Kühn [8] analyzes the evolution of verification regimes within the framework of the Treaty on the Non-Proliferation of Nuclear Weapons and bilateral agreements on strategic arms, emphasizing the growing role of national technical means of verification and analysis of open sources. The authors conclude that the effectiveness of verification is possible only under the conditions of creating hybrid systems in which state intelligence agencies cooperate with international organizations and the commercial sector within the framework of clearly defined data exchange protocols. R. Allison [1] examines mechanisms for preventing escalation during the Russian-Ukrainian war, taking into account the nuclear dimension. Particular attention is paid to the effectiveness of early detection of preparations for the possible use of nuclear weapons using electronic reconnaissance and satellite monitoring. The author notes that institutional inertia and the lack of unified protocols for information exchange with non-nuclear partners reduce the overall adaptability of existing control regimes.

M. S. Bell [4] revises classical theories of nuclear deterrence in the context of modern conflicts and points out the lack of consideration of intelligence asymmetry. Non-nuclear-weapon states are forced to rely on external sources of information, while the breaching party uses information opacity to manipulate the level of risk. Based on this, it is concluded that there is a need to institutionalize multilateral intelligence sharing as a condition for restoring trust. A. K. Arndt, L. Horowitz and M. Onderko [3] demonstrate on empirical material that the operational exchange of intelligence information within NATO and the public disclosure of the aggressor's intentions significantly reduced the effectiveness of nuclear coercion attempts in 2022–2024, which confirms the potential of intelligence tools as an active means of countering coercion even in the context of a partial collapse of the treaty system. D. Santoro [14] considers the prospects for the creation of verification mechanisms with the participation of new nuclear states and proposes the phased use of commercial satellite data and open-source analysis as a transitional stage to full-fledged multilateral regimes.

Despite a significant number of publications, most studies remain focused on the bilateral US-Russia format and do not sufficiently take into account the needs of non-nuclear states in a multipolar environment. There are practically no integrated models that would combine international experience, modern technologies of automated analysis and specific security needs of countries in the process of Euro-Atlantic integration. Although academic opinion states the transition to technology-oriented verification, there is a lack of a systematized technological project, a detailed description of data architecture, interfaces for integrating various intelligence tools and protocols for their use in legal regimes. It is this gap, the design of a technological platform for new verification, that this article fills.

3. Problem Statement

The article is aimed at developing a conceptual model for the integration of intelligence support into the mechanisms of verification and control of nuclear missile weapons, taking into account the current state of international legal regimes and the strategic needs of Ukraine.

To achieve the goal, the following tasks have been set:

1. To analyze the limitations of the current verification mechanisms and the reasons for their insufficient effectiveness in the context of weakening of the contractual framework.
2. Determine the role of various intelligence tools (national technical means of control, open-source analysis, electronic intelligence, satellite surveillance) in ensuring transparency and strategic stability.
3. To investigate the impact of modern conflicts on the transformation of approaches to verification and deterrence.
4. Propose a three-tier model of adaptive intelligence support for future international agreements involving Ukraine.

Formulate practical recommendations for the state bodies of Ukraine and international partners on the institutional consolidation of intelligence functions in security arrangements.

4. Methods and Materials

The methodological basis of the study is a complex of general scientific and special methods of cognition, the application of which is due to the interdisciplinary nature of the problem of integrating intelligence support into the mechanisms of verification and control of nuclear missile weapons. The paper uses a systematic approach, which made it possible to consider international legal arms control regimes as complex dynamic systems in which legal, institutional, technological and security components are closely interconnected and interdependent. The application of system analysis made it possible to identify structural dysfunctions of the current verification regimes in the context of a weakening of the contractual framework and to determine the place of intelligence tools as a backbone element of the new strategic stability architecture.

Theoretical methods of analysis, synthesis, generalization and comparison are used to study scientific publications of leading foreign and domestic researchers in the field of international security, nuclear deterrence, arms control and intelligence research. The comparative legal method made it possible to compare the evolution of key international agreements in the field of nuclear missile weapons, their current status and the transformation of verification mechanisms in the context of the actual curtailment of inspection procedures. Based on this, the regularities of the transition from the contractual and inspection model of control to hybrid, technologically oriented forms of monitoring were determined.

5. Results and Discussion

Reconnaissance tools turn from a compensatory agent into a system-forming one. However, this raises a new problem: the modern reconnaissance panorama is scattered and asymmetrical. The data is stored in national databases, the formats for their processing vary, and the access of non-nuclear states (such as Ukraine) to them is limited and indirect, which creates a technological barrier to effective verification. Therefore, the key task is not just to state the importance of intelligence, but to design mechanisms for its integration, standardization and legitimation in the international legal field (Table 1).

The analysis of Table 1 demonstrates a direct link between the erosion of classical contractual mechanisms and the growing critical role of intelligence tools in verification. Each identified challenge – from political paralysis to the complete rupture of inspection regimes – is directly translated into specific intelligence tasks: compensating for the lack of transparency, monitoring unlimited systems, and providing the foundations for new, technology-oriented control regimes. The crisis of the contractual framework not only weakens the old security architecture, but also directly forms the requirements for the new one, in which intelligence support ceases to be an auxiliary tool and becomes a backbone element. Such a transition is especially relevant for states that, like Ukraine, rely on collective security guarantees and need reliable tools for independent monitoring of their compliance.

Table 1. Key International Agreements on Nuclear Missile Arms Control: Current Status and Main Challenges

Deal	Current status	Key challenge for verification	Implications for intelligence support
Treaty on the Non-Proliferation of Nuclear Weapons	Incumbent but politically paralyzed	Lack of mechanisms for coercion and audit of military programs of nuclear powers.	Transition to indirect monitoring. The growing importance of open-source analysis, commercial satellite data, and signal intelligence to detect signs of proliferation and undeclared activity.
Strategic Arms Reduction Treaty	The participation of the Russian Federation is suspended; The action ends in 2026.	Complete loss of direct inspections and transparency on the state of strategic arsenals.	Intelligence becomes the main source of information. Critical reliance on national technical means, satellite surveillance and electronic reconnaissance to track carriers and warheads.
Treaty on the Elimination of Intermediate-Range and Short-Range Missiles	Terminated in 2019	Lack of any legal restrictions and verification mechanisms for this class of missiles.	Monitoring is turning into an intelligence task. Active use of geospatial intelligence to detect the deployment of new missile systems not limited by the treaty.

Source: Compiled by the author based on [2; 5; 7; 15–18].

Intelligence asymmetry plays a special role: non-nuclear states, such as Ukraine, depend on external sources – satellite surveillance, open data analysis, and exchanges within NATO, while the opponent uses opacity to mask actions [4]. The ineffectiveness of Russian attempts at nuclear coercion in 2022–2024 is attributed to NATO's rapid data sharing (satellite surveillance, electronic intelligence) and rapid disclosure of information through open-source communities [3], demonstrating how modern deterrence is based on information openness and multi-channel verification.

The experience of the conflict in Ukraine stimulates a review of the role of intelligence in safeguards mechanisms. The use of space-based surveillance means, stable data channels and agreements for the exchange of information between states form a new monitoring system [13]. First, security guarantees require constant monitoring of the doctrinal changes of the guarantor states using hybrid verification models based on open sources and commercial satellite data as a transitional stage to inspections [18]. Secondly, artificial intelligence is becoming a tool for intelligence analysis – automated detection of deviations in information flows increases the accuracy of forecasts and the efficiency of response [5]. Thirdly, the institutionalization of data exchange, in particular according to NATO practices, should become a component of new guarantees. The exchange between Ukraine and the Alliance through the Joint Intelligence and Security Division has become systematic, complemented by open-source analysis standards for legal weight [10]. Without this, new mechanisms risk repeating the mistakes of the past, and international law risks losing its effectiveness against revisionism. Technological changes, including the integration of artificial intelligence into nuclear force control systems, increase risks and complicate verification [12]. Reconnaissance tools in modern conditions are becoming a key element in maintaining balance. If earlier verification was based on mutual trust of states and inspection procedures, now monitoring through different channels, signal processing and analysis of cyber threats compensates for the weakening of institutions [6; 9; 11].

The technical aspect of risks is exacerbated by cyber threats: penetration of missile control systems, manipulation of remote monitoring data, and the use of artificial intelligence to attack early detection systems create vulnerabilities in national technical controls, which were the basis of arms agreements [12].

As Table 2 shows, the strategic stability crisis is multifaceted: each challenge increases the vulnerability of the system, emphasizing the speed and accuracy of intelligence analytics as a means of maintaining balance. The proposed model of integration of intelligence support into international control regimes provides for three interrelated levels of reform.

– *Organizational level.* It is expedient to establish an International Nuclear Risk Monitoring Center with the participation of NATO, IAEA, the EU and Ukraine. The Center will act as a hub for the exchange of data from open sources, electronic and human intelligence, with annual reports on compliance with obligations [13].

– *Technological level.* It is recommended to expand the use of commercial sources (Maxar, Planet Labs), space-based surveillance systems, and artificial intelligence models for predicting escalation. The

integration of electronic intelligence with machine learning algorithms will create a dynamic system for predicting changes in the behavior of violating states [9; 12].

Table 2. Current Challenges to Strategic Stability and Countering Intelligence Tasks (as of 2025)

Challenge	Description	Impact on strategic stability	Reconnaissance task
Nuclear coercion of the Russian Federation	Systematic Threats of Escalation, Doctrine Update (2024) [6;11]	Weakening of containment norms; erosion of trust in the NPT	Predicting Intent through Electronic Intelligence and Doctrine Analysis
Deployment of tactical nuclear weapons in Belarus	Movement of warheads from 2023; lack of verification [6]	Regional destabilization; risk of NATO-Russia confrontation	Motion monitoring via satellite observation/open-source analysis (Maxar satellites)
Escalation doctrine for de-escalation	Limited nuclear use for de-escalation [9]	Blurring the boundaries of conventional and nuclear war; Increased risks	Analysis of escalation indicators (human intelligence, automated forecast models)
Cyber threats to nuclear infrastructure	Attacks on control systems; AI integration [12]	Undermining verification; creation of "blind spots" in monitoring	Detection of cyber incidents through electronic intelligence and automated analysis

Source: Compiled by the author based on [6; 9; 11; 12; 13].

– *Regulatory level.* It is necessary to consolidate automatic sanctions for confirmed violations, conduct an audit of security assurances (annual reports of the center) and move from political agreements to binding treaties with data exchange protocols [11], which will allow the transition from a reactive to a preventive approach.

The proposed three-level model requires a specific technological implementation in the form of a Hybrid Intelligence and Analytical Platform (GRAP). Its core should be not just an exchange center, but a system with a unified digital environment that integrates heterogeneous sources:

– *Data layer:* automated pipelines for receiving and preprocessing data from commercial satellites (Maxar, Planet), state electronic warfare systems, public information sources (social networks, public procurement) and IAEA sensor networks.

– *Analytics layer:* a set of algorithmic modules (artificial intelligence/machine learning) to perform specific tasks: automatic pattern recognition in snapshots to detect construction; semantic analysis of rhetoric to identify threat patterns; network analysis to identify supply chains.

Presentation and protocol layer: standardized application programming interfaces for secure access by authorized users, automatic report generators, and "digital traces" to capture the origin of data and analysis results, which is critical for the legitimacy of conclusions.

The creation of such a center (technological hub) is a practical prerequisite for the functioning of any institute for the audit of intentions, providing it with objective, technologically verified information raw materials for analysis. Such a platform is not a substitute for national intelligence services, but acts as a technological synergistic multiplier that transforms disparate data into a common operational picture for decision-making. Modern challenges require a conceptual shift towards intelligence as the basis of international security regimes. In the new model, data sharing provides trust, and institutionalized transparency maintains stability. The reform involves not only a technical update, but also a legal rethinking of contracts, with liability norms, sanctions mechanisms and audit of assurances for a comprehensive preventive system.

6. Conclusions

The analysis confirms that the system of international regulation of nuclear and missile weapons is experiencing a structural crisis due to the obsolescence of legal norms, fragmentation of institutions and the rapid evolution of threats. The main drawback, the lack of tools for liability for violations, turns regimes into declarative constructions, which requires the creation of a new contractual framework with a combination of legal obligations and independent verification. Intelligence functions in such a system become the basis of security, ensuring the transition from reactive surveillance to preventive risk management. Their integration forms a model of analytical trust, where information transparency and technological predictability are the key to stability. Ukraine, based on the experience of weakening political assurances and developing monitoring in conflict conditions, can become a platform for testing a new system of collective security, where sanctions mechanisms, audit of assurances and international coordination form a single preventive complex.

Our state, having a unique combat experience in countering aggression using modern monitoring technologies, can become not only a "pilot site", but an active developer of standards and components of such a hybrid platform. The creation of the national segment of the GRAP and its integration into the systems of cooperation with NATO and the EU is a concrete step to transform Ukraine from an object of guarantees into a subject of the technological architecture of the future global security system.

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