International security regimes in preventing the spread of nuclear armaments and their global significance

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Abstract:

Introduction/purpose: The paper provides an overview of international regimes and agreements that aimed to halt the spread of nuclear weapons. For each regime, its impact on nuclear weapons proliferation is presented, as well as its significance in stopping nuclear tests that posed a threat of a global ecological catastrophe. Many of these regimes are no longer in effect today, but throughout history, they played their role in fulfilling specific needs to halt the global spread of nuclear weapons or characteristic nuclear weapons of a certain range.

Methods: The paper analyses the international agreements in this field, as well as the papers in the field of nuclear safety from journals of international importance.

Results: The analysis of nuclear security regimes gave results that speak of their strengths and weaknesses. The importance and weaknesses of the regimes are given through the analysis and several diagrams that show the trend of increasing the amount of nuclear weapons over time.

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Conclusions: The work points to the historical importance of nuclear security regimes, but also to their weaknesses, both in earlier times and today. It is clear that these regimes halted nuclear weapons, but this halt did not lead to the complete abolition of nuclear weapons, which is the ultimate goal of the agreements.

Key words: security regimes, nuclear weapons, proliferation, nuclear tests, international agreements.

Introduction

The moment World War II ended, the threat to humanity did not diminish; on the contrary, it became even greater and continued to escalate day by day. Those dark clouds looming over humanity stem from the potential escalation of conflicts among nuclear powers, which would inevitably lead to a nuclear war, effectively marking the beginning of a nuclear winter (Coupe et al, 2019; Vilhelmsson & Baum, 2023).

Even when people survive a nuclear catastrophe or exposure to radioactive radiation, they endure lasting health consequences (Boice et al, 2022; Šefl et al, 2021).

The fear of Armageddon and nuclear winter did not always exist. In fact, at the very beginning of the development of nuclear weapons, American authorities did not take intelligence reports about the Nazi nuclear program seriously. Albert Einstein played a crucial role in this regard; he was already a prominent figure at the time and managed to persuade the US authorities to initiate a nuclear program. The Manhattan Project, after several years, ultimately provided the world with nuclear weapons (Reed, 2015; Chadwick, 2021; Andrews et al, 2021).

The race in nuclear armament was initiated by the authorities of Nazi Germany. Subsequently, the United States of America took the lead, but had to continue the race with the Soviet Union in 1949. Soon, other countries also joined the race (Sood et al, 2021).

The first atomic, or fission, bomb was detonated in 1945 (Beck et al, 2020), while the first thermonuclear bomb was tested in 1952 (Hain et al, 2020; Krass et al, 2022). Today, a total of nine countries possess nuclear weapons. These include the five permanent members of the UN Security Council (the USA, Russia, China, the UK, and France), as well as India, Pakistan, Israel, and North Korea. There are various criteria for classifying nuclear weapons. Apart from the basic division based on the nuclear reaction they rely on, weapons can also be classified by warhead strength, delivery method to the target, missile range, and more. Perhaps the most fundamental classification would be based on the weapon's purpose. In

this case, weaponry could be categorized into strategic nuclear weapons and tactical nuclear weapons.

Due to all the aforementioned reasons, it is evident that there is a substantial need for educating the general population and implementing nuclear security regimes. All protocols and standards related to nuclear safety are of utmost importance (Nikač et al, 2022), and there are a significant number of articles discussing this (Mianji et al, 2013; D'auria & Galassi, 2019; Tsai, 2017). Agreements to halt the spread of nuclear weapons are particularly crucial due to the serious challenges currently faced by the international community.

The need for this research arises from the inherent significance of the topic, its complexity, and its essential importance to human civilization as a whole. The existence of nuclear weapons constantly casts a shadow of a potential catastrophe over mankind. Preventing the spread of nuclear weapons and their reduction, even complete elimination, are highly intricate issues, especially considering that throughout history, the world has been polarized and continues to be, perhaps more than ever. We have always had two sides engaged in power-demonstrating games. In World War II, it was Germany and its allies against America and its allies. This competition persisted through the Cold War and continues to this day, albeit with participants arranged slightly differently. During the Cold War, the USSR and the Warsaw Pact were on one side and the USA and NATO on the other, while today the world is largely divided into the East and the West.

A new threat of nuclear terrorism has emerged in recent times. Terrorist organizations may not have the capability to possess nuclear arsenals, but they do have the potential to use various other methods to spread fear through nuclear terrorism. Firstly, there are radiological "dirty" bombs, then contamination through stolen radioactive sources, as well as attacks on nuclear power plants (Gale & Armitage, 2018; Leikin et al, 2003).

The aim of this study is a systematic compilation of knowledge about nuclear security regimes (from the first initiative in 1953 to the present day), as well as in examining their abuses, compliance, and the double standards in their implementation. Additionally, the study aims to highlight the historical development and significance of the IAEA, while addressing the gravity of the global situation due to the existence of nuclear weapons. Furthermore, it seeks to contribute to the acquisition of knowledge crucial for the prohibition of the proliferation of these armaments.

The significance of this research is underscored by the question: How much have international security regimes truly contributed to the reduction of nuclear weapons?

International security regimes in preventing the proliferation of nuclear weapons

International nuclear security regimes encompass a range of multilateral and bilateral agreements and arrangements between states aimed at avoiding conflicts, particularly those of a nuclear nature.

The enforcer in implementing these agreements is the International Atomic Energy Agency (IAEA) (Krass et al, 2022).

The first substantial initiative to halt the spread of nuclear weapons emerged in 1953 when U.S. President Eisenhower delivered the "Atoms for Peace" speech before the UN (Krass et al, 2022). Subsequently, the establishment of the IAEA followed, along with the creation of numerous international agreements and a significant number of bilateral nuclear agreements between the USA and the USSR (Russia).

Non-proliferation treaty (NPT)

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) (IAEA, 1970) is not the first agreement within the realm of international security regimes aimed at halting the spread of nuclear weapons. However, it is the first one that defined which states are recognized as declared nuclear powers and introduced practical measures to prevent further nuclear weapon proliferation. This treaty serves as one of the cornerstones upon which international nuclear security regimes are built and it could arguably be considered the most important or central nuclear security agreement (Cooper, 2023).

The adoption of this international agreement was preceded by multi-year, or perhaps even better to say, multi-decade initiatives for the abolition of all forms of nuclear weapons. One of the most important initiatives is the previously mentioned "Atoms for Peace" initiative. It was of fundamental importance for the establishment of the IAEA, and the existence of the Agency contributed to the eventual achievement of the Treaty. Nevertheless, it took time for this to happen, as more than ten years passed from the establishment of the IAEA to the adoption of the NPT. The Treaty was adopted in 1968 and came into force two years later, in 1970, when it was signed by over 90 countries and ratified by 47. Currently, it has 191 valid signatories (IAEA, 2022), with the exception of North Korea, which withdrew from the Treaty in 2003 (IAEA, 2024).

Representatives of India, Pakistan, South Sudan, and Israel never signed the NPT (United Nations, 1968).

In 1968, when this act was adopted, the first countries to sign it were the USA, the USSR (today's Russian Federation), and the UK. These states were designated as Depositary Governments in 1970 when the Agreement came into effect (Cooper, 2023).

According to Article III, paragraph IX of the Agreement, all signing states are divided into two groups: Nuclear Weapon States (NWS) and Non-Nuclear Weapon States (NNWS). NWS includes all states that possessed nuclear weapons before 1967, namely: the USA, Russia (USSR), China, Great Britain, and France. This created a significant divide between states categorized as NWS and those in the NNWS group. Some NNWS were on the brink of testing their nuclear weapons at that time but could not do so if they signed the Agreement. This is why India, Israel, and Pakistan have never accepted being part of the Agreement in any way. Apart from these states, which are considered de facto nuclear-armed states today, other countries accepted the NNWS status and signed the NPT with firm assurances that NWS would aid them in the development of peaceful nuclear programs (Bunn, 2003).

The Treaty sets forth three fundamental goals to which all signatory states should strive: the cessation of nuclear weapons proliferation, the complete disarmament of these weapons, and comprehensive cooperation in the peaceful use of nuclear energy. The agreement defines the fundamental obligations of NWS. The obligations of these five states are not to transfer their weaponry to other states in any manner and not to assist or encourage the development of nuclear programs that could be used for armament purposes. The states in the NNWS group are obliged not to accept offers from other states to participate in the development of programs intended for armament purposes of this kind, nor to accept the transfer of such weaponry from any other state. The Treaty defines the role of the IAEA within the monitoring system. NNWS states undertake to allow a system of control during the production of fissile materials used for peaceful purposes and during their exchange with other states. The Agency commits not to impede the technological and economic prosperity of these states in any way, nor their cooperation in peaceful activities. Each of the signatory parties has the right to withdraw from the NPT if it deems there are extraordinary events that jeopardize the fulfillment of the Agreement.

Comprehensive nuclear-test-ban treaty

Nuclear tests can be categorized into four groups: underwater - in oceans and seas, atmospheric - in the atmosphere, exoatmospheric - above the atmosphere, and underground - beneath the Earth's surface (Wiesner & York, 1964). The Comprehensive Nuclear-Test-Ban Treaty (CTBT) has prohibited all four types of tests.

The agreement is the result of decades-long efforts to establish a ban on testing in order to preserve the environment. Prior to this Agreement, there were other initiatives, but this is the first comprehensive treaty, which is why it is a crucial factor in nuclear security regimes.

The draft of the Agreement was presented on September 10, 1996, by the United Nations General Assembly, and signing followed four days later. All five declared nuclear-armed states signed this document, but despite that, it has not yet come into force. Namely, in addition to signatures, it needs to be ratified, and for it to take effect, it must be signed and ratified by all states that possess any form of nuclear technology within their territories. The total number of states possessing nuclear reactors and using nuclear energy is 44. These are the states listed in Annex 2 of this Agreement. Therefore, it is necessary for all these states to ratify the Agreement for it to come into force. Out of the 44 states listed in Annex 2 of the Agreement, 5 have not ratified the treaty - the USA, China, Iran, Israel, and Egypt. Three states from this annex have not even signed it - North Korea, Pakistan, and India (NTI, 1996). It is precisely these three states that conducted nuclear tests even after the CTBT was open for signing and ratification, which clarifies why these specific states have not even engaged in signing this Agreement.

With this Agreement, all countries are called to stop nuclear testing to prevent nuclear weapon proliferation, which further leads to "the cessation of the arms race and disarmament under strict and effective international control". Through this Agreement document, the member states established the Comprehensive Nuclear-Test-Ban Treaty Organization. The primary purpose of the Organization lies in ensuring the implementation of the agreed upon terms. The headquarters are located in Vienna, and the bodies of the Organization include the Conference of States Parties, the Executive Council, and the Provisional Technical Secretariat, which also encompasses the International Data Centre. The Agreement also defines the conditions for data confidentiality and the exchange of information between the Organization and individual states, as well as the financing of the Organization. The member states fund this body, and any member failing to meet its obligations loses its voting rights.

Furthermore, the Treaty specifies the organizational structure and thoroughly defines various bodies constituting it - the Conference of States Parties, the Executive Council, and the Technical Secretariat, along with their functions, privileges, and immunities. The verification system consists of the International Monitoring System, the Consultation and Clarification Process, on-site inspection, and confidence-building measures. An International Data Centre is introduced, defined as the central hub within the Provisional Technical Secretariat, receiving data from the International Monitoring System or on-site inspections and managing them. The Center supports the System, comprising seismic monitoring stations, radionuclide monitoring, hydroacoustic monitoring, infrasound monitoring, and data transmission capabilities. Furthermore, the Agreement also regulates the rights and obligations of the member states, the modes of withdrawal, the circumstances leading to the denial of rights, and define the depository of the Agreement - the UN Secretary-General.

The Protocol to the Comprehensive Nuclear-Test-Ban Treaty elaborates further on the functions of the International Monitoring System and the International Data Centre (NTI, 1996; Ahn et al, 2021).

Bilateral agreements between the USA and the USSR (today's Russia)

Bilateral agreements, as a type of a nuclear security regime, have been primarily signed between the United States of America and the USSR (today's Russia), the two states that engaged most intensely in the race for nuclear power. These states possess the largest number of nuclear warheads (Akiyama, 2020), making them the two most powerful nuclear nations in the world. Any agreement between them would result in changes to the international landscape. In this context, the agreements reached between the United States of America and the USSR (Russia) represents significant security outcomes, even though they do not encompass the entire international community; rather, their adherence is conditioned by the bilateral relationship between the two sides.

To this day, these two states have signed a series of bilateral agreements concerning the cessation of the nuclear arms race and the reduction of the number of nuclear missiles. Some agreements never came into force. The first agreement, named SALT I, was signed in 1972. This was followed by the ABM Treaty, signed on the same date as SALT I, and then the TTBT, signed in 1974, which came into force in 1990, and SALT II, signed in 1979, but never came into force as the USA side never ratified it in protest of the Soviet war in Afghanistan. The INF Treaty was agreed upon in 1987, came into force the following year, and was fully

implemented by 1991. In 1991, when a new climate in the relations between the two countries emerged, START I was signed, replacing the SALT agreements. It came into force in 1994. After the dissolution of the USSR in 1991, it was necessary to define which state succeeded the former state's nuclear program. This was agreed upon through the Lisbon Protocol, signed in 1992 (Kurosawa, 2021), which allowed the implementation of the new situation in the East within the framework of START I. Belarus, Kazakhstan, and Ukraine renounced nuclear weapons through the Protocol and committed to joining the NPT. Russia was declared the successor to the former state's nuclear program. In 1993, START II was signed, but it never came into force. The deadline for fulfilling the agreed conditions was the end of 2003. Due to the dynamics of meeting these conditions, it was agreed in 1997 to extend the deadline until the end of 2007. At that time, the parties envisaged the signing of the START III agreement in 2007. Meanwhile, in 2002, the SORT or Moscow Treaty, as it is alternatively known, was signed, along with the Declaration on Strategic Partnership between the United States and the Russian Federation. This agreement marked the end of the "START" agreements, so START III remained in the plan and was never realized. The "New START" is the latest agreement in this series, signed in 2010 and coming into force in 2011 (Akiyama, 2020; Kurosawa, 2021; Puentes et al, 2020).

SALT I – Strategic Arms Limitation Talks "freezes" the current state in terms of the number of strategic nuclear missiles until an agreement is reached for the complete elimination of nuclear weapons (Kurosawa, 2021).

ABM or ABMT – Anti-Ballistic Missile Treaty limits the development of anti-ballistic missile systems of the two countries. The agreement restricts the number of anti-ballistic missiles to a maximum of 100. It was valid for 30 years and is believed to have prevented the placement of anti-ballistic missile systems in space. The United States withdrew from the agreement in 2002 and established the Missile Defense Agency, ending the validity of the agreement. Along with the agreement, the idea called MAD – Mutually Assured Destruction came into effect. This idea predicted that if one country launched a nuclear attack on another, the other country had the right to respond in kind, without any attempts by the first country to defend itself. Thus, this idea guaranteed equal damage in the event of a nuclear conflict.

TTBT – Threshold Test Ban Treaty restricts the yield of underground nuclear tests to 150 kt considering that there was already a Partial Test Ban Treaty in place at that time, which will be discussed in the next chapter. It can be concluded that this treaty slowly led to the CTBT.

INF – Intermediate-range Nuclear Forces Treaty is an agreement to eliminate all missiles with ranges between 500 and 5500 km. This includes all ballistic and land-launched cruise missiles. Submarine-launched missiles are not covered by this agreement. Since 2014, both sides have made mutual accusations of violating the INF Treaty. The USA finally withdrew from the treaty in 2019, blaming Russia as the main culprit for this course of events (Akiyama, 2020; Kurosawa, 2021; Puentes et al, 2020).

Since the dissolution of the USSR, four more agreements have been signed: START I, START II, SORT, and New START. START stands for Strategic Arms Reduction Treaty and, as already mentioned, aimed to replace the SALT agreements, which did not meet expectations. Each of the START agreements had the same significance and similar goals: primarily reducing and then limiting the number of strategic nuclear missiles of both parties to prevent further growth. It was envisaged that the parties would agree on deadlines for achieving specific tasks regarding the reduction of warheads, and then after a certain period, agree on new tasks, continuing until the last nuclear missile was eliminated. However, it is evident that there is no serious political will for this, so we must wait and see what the last agreed-upon treaty, called New START, will bring. It was expected to fulfill its obligations by February 2021 or be extended until 2026. During those years, the USA sought to include China in the Treaty from 2021, considering China a threat due to its close cooperation with Russia and the development of more advanced ICBMs by China (Akiyama, 2020). However, this did not happen. The treaty was extended for another 5 years in 2021, but in the meantime (2023) President Putin suspended it due to the USA involvement in the war in Ukraine (Bugos, 2023).

International Convention for the Suppression of Acts of Nuclear Terrorism

The International Convention for the Suppression of Acts of Nuclear Terrorism (CNT) (United Nations, 2005) was opened for signature in September 2005 at the United Nations and entered into force in July 2007. Its purpose is to criminalize acts of nuclear terrorism, define measures for sanctioning involved parties in case of such acts, and enhance cooperation between investigative and enforcement authorities to prevent and combat nuclear terrorism, one of the most undesirable forms of terrorism. Currently, the Convention has been signed by 115 parties and has 120 state participants (NTI, 2005).

The agreement covers a wide range of potential attacks and targets, including nuclear facilities such as nuclear reactors. Threats and attempts to commit crimes are defined, as well as the concept of complicity in case of nuclear terrorism acts, and the methods of sanctioning each of these offenses are outlined. States parties are encouraged to collaborate, as well as to conclude bilateral or multilateral regional agreements aimed at countering all forms of nuclear terrorism. The Convention calls for information sharing, police assistance, peaceful conflict resolution, and crisis management support.

The IAEA is guaranteed to provide assistance under the Convention in dealing with crises related to nuclear terrorism and the removal of undesirable radioactive materials from the territory of an affected state. The Secretary-General of the United Nations is appointed as the depositary.

The Convention is a result of states efforts to enhance international cooperation to prevent acts of nuclear terrorism and was enacted for this purpose. Moreover, the Convention aims to curb cooperation between states and terrorist organizations in terms of the use of any nuclear isotopes or weapons employing such isotopes. This approach prevents secret state actions through terrorist organizations and thus helps to prevent the escalation of conflicts between nuclear powers.

Remaining agreements that can be classified within nuclear security regimes

There is a whole range of agreements that cannot be directly classified as nuclear security regimes due to their nature, primarily because they were established to regulate other contentious issues in the field of international law. Issues related to nuclear weapons are only mentioned in certain articles of these documents and pertain to resolving nuclear weapon matters within the framework of another larger international dispute, the resolution of which involves the enactment of agreements. On the other hand, there are agreements that address specific nuclear security issues, but their uniqueness, which prevents us from describing them as part of the current security regimes, lies in the fact that they have been supplemented over time and accepted by the international community in the form of new comprehensive agreements.

The Antarctic Treaty, along with other agreements related to Antarctica, is part of the Antarctic Treaty System (ATS). This document defines Antarctica as an uninhabited continent encompassing the entire landmass and all ice-covered areas south of 60° south latitude. The Antarctic Treaty was opened for signature in 1959, and to this day, a total

of 53 states have signed it (NTI, 1959). In a way, this document represents the first nuclear security regime. Specifically, it prohibits military activity on the continent's territory, particularly nuclear explosions and the storage of nuclear waste on the Antarctic land. Therefore, this is the first agreement that prohibits the use of nuclear weapons in a specific region, making it partly a security regime.

The Partial Nuclear Test Ban Treaty (PTBT) was adopted in 1963. The full title of this document is the Treaty Banning Nuclear Tests in the Atmosphere, in Outer Space, and Under Water. As the full title of the Treaty suggests, it essentially serves as a document that prohibits three out of the four mentioned types of nuclear tests: atmospheric, exoatmospheric, and underwater. However, the Treaty did not ban underground tests, so nuclear testing not only did not cease but continued even more intensively, with the exception that tests were conducted only below the Earth's surface. The Treaty defines two groups of tests that are prohibited: a) atmospheric, and b) all tests conducted in any other environment if there is a possibility of nuclear waste dispersal beyond the borders of the testing state. Of course, it is clear that exoatmospheric and underwater nuclear tests fall into this second category. Furthermore, the Treaty states that this prohibition does not prejudge the ban on underground tests, aiming for a comprehensive prohibition of nuclear tests.

The Outer Space Treaty, formally known as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, was presented in late 1966 and adopted on October 10, 1967. The adoption of this treaty was preceded by significant diplomatic efforts, primarily between the United States of America and the Soviet Union (Johnson-Freese, 2017), as well as among all nuclear powers and other states worldwide. From the beginning of the Cold War, politicians from both sides recognized the potential of space and the possibilities that placing nuclear weapons in Earth's orbit, on the Moon, and other celestial bodies could bring. When the Soviet Union successfully launched the first artificial satellite into Earth's orbit in 1957, certain factions in the United States, influenced by this event and fearing that the Soviet Union could pose a threat given its achievement in conquering part of space, urged then-President Eisenhower to initiate a program that would lead to the deployment of nuclear missiles in space. Eisenhower rejected this idea and began advocating for the use of space exclusively for peaceful and scientific purposes before the international community (Vlajnić, 2015). Following that, several resolutions and declarations were adopted over the next

decade that eventually led to the formulation of the Outer Space Treaty. The specificity of this document is that it does not strictly pertain to nuclear weapons, but rather to all forms of military technology. However, it is evident that it was primarily adopted due to nuclear weapons, as emphasized in Article IV, which prohibits nuclear weapons.

The Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Sea-Bed and the Ocean Floor and in the Subsoil thereof, commonly referred to as the Seabed Treaty, adopted in 1971, is also one of the security regimes introduced to prevent the spread of nuclear weapons to undesirable areas and to avoid further environmental contamination. It pertains to a specific area and is introduced to protect a part of the living world. In the preamble of the Treaty, the contracting parties are encouraged to engage in peaceful research of marine and oceanic areas. On the other hand, they are called upon to halt the arms race in nuclear weapon development, which is the context of this document. The Treaty is considered a step forward toward ultimate disarmament. All signatory states are prohibited from storing nuclear weapons or any weapons of mass destruction on the seabed or beneath its surface. Therefore, this treaty also does not explicitly focus on nuclear weapons, but it is more than clear that it was introduced primarily due to this type of weaponry, which can be inferred by analogy with the Space Treaty.

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, commonly referred to as the Moon Agreement, from 1979, could be seen as a supplement to the Outer Space Treaty, providing more precise definitions of obligations regarding the use of the Moon. The Moon Agreement, in a way, "fills in legal gaps" that existed within the Outer Space Treaty.

The Fissile Material Cutoff Treaty (FMCT) is one of the agreements that remained only in proposal. The first proposal for such a treaty was put forward in 1993 by then-President of the United States, Bill Clinton. Several ideas were suggested regarding this agreement, either by the United States of America or Russia, but none was accepted. Such a treaty would ban the production of certain fissile materials known to be used as fuel in nuclear bombs. The challenges mainly arise in defining nuclear fuels used for military purposes. Even today, a clear proposal for this treaty does not exist, despite several attempts to reach an agreement.

This is one of the main topics of the Conference on Disarmament (CD), established in 1995 following the adoption of UN Resolution 48/75L. The resolution calls for the elimination of fissile materials used for nuclear weapons. The CD deals with the elimination of all types of weapons of

mass destruction and has made multiple attempts to present the FMCT. In 2006, the International Panel on Fission Materials (IPFM) was even established with the purpose of promoting nuclear disarmament and the cessation of production of fissile materials used for military purposes. In 2009, this body presented its version of the FMCT, which somewhat represents the organization's statute. The organization consists of numerous experts in the field of nuclear physics from a total of 18 countries, including the United States of America and Russia (NTI, 2024).

It is unfortunate that the treaty has not come into force within the framework of the UN. However, many conditions of the Nuclear Non-Proliferation Treaty (NPT) and other security regimes call on states to refrain from producing highly enriched uranium and plutonium used for the construction of atomic and thermonuclear bombs. In a way, this makes the treaty somewhat redundant. It is also important to note that the International Atomic Energy Agency (IAEA) has mechanisms through which it can detect the production of prohibited fuels through its inspectors, as will be discussed in the following chapter.

The Nuclear-Weapons-Free Zones (NWFZ) is also part of the group of security regimes. This group includes The Antarctic Treaty, the Outer Space Treaty, and the Seabed Treaty, among others. However, due to the fact that these zones are uninhabited, they can also be regarded as distinct agreements. In a narrower sense, the NWFZ includes: the Treaty for the Prohibition of Nuclear Weapons in Latin America, commonly known as the Treaty of Tlatelolco from 1967, the South Pacific Nuclear-Free-Zone Treaty, also known as the Treaty of Rarotonga from 1985, the Southeast Asian Nuclear-Weapon-Free Zone Treat or Treaty of Bangkok from 1995, the African Nuclear-Free-Zone Treaty, known as the Treaty of Pelindaba from 1996, and the Central Asian Nuclear-Weapon-Free Zone Treaty, also known as the Treaty of Semipalatinsk from 2006. As the names of these agreements suggest, they establish certain regions, in consultation with the nations in those regions, as zones free of any form of nuclear energy-related military application (United Nations, 2006; IAEA, 2015).

The Treaty on the Prohibition of Nuclear Weapons (TPNW) is the latest addition to the series of international nuclear security regimes. The treaty was opened for signing in 2017 and came into effect in 2021. In comparison to previous agreements, this treaty takes an extremely radical approach towards the complete elimination of nuclear weaponry (Ruff, 2022). It appears that this regime lacks significant influence, as none of the nuclear-armed states, whether recognized (NWS) or unrecognized (India, Pakistan, North Korea, and Israel), participate in it.

IAEA as the guarantor of the regime implementation

"The IAEA (International Atomic Energy Agency) is an international organization that serves as the leading global intergovernmental forum for coordinating scientific and technical cooperation in the peaceful use of nuclear energy and nuclear technologies. It also operates as an international inspectorate for the implementation of nuclear inspection measures, verifying activities related to civil nuclear programs. Established in 1957 as an independent organization under the umbrella of the United Nations, it now encompasses a wide range of services, programs, and activities based on the needs of its 176 member states. The Agency, headquartered in Vienna, has offices at the UN in New York, Rome, and Geneva, inspection offices in Toronto and Tokyo, and laboratories in Austria and Monaco. It also supports a research center in Trieste under the auspices of UNESCO. The strategy and policies of the Agency are determined based on the recommendations from the Board of Governors at the General Conference. The Secretariat, led by a Director-General and six Deputy Directors-General responsible for specific areas, manages the implementation of programs and activities" (IAEA, 2023).

IAEA inspection oversight

The inspection system, in a way, represents the executive body within nuclear security regimes. The establishment of the inspection system was awaited for two years after the founding of the Agency. It was agreed upon in Canada in 1959; however, the document regulating the functioning of this body was awaited for just as long. In 1961, the first document was signed, regulating the procedures for the application and instructions for the work of IAEA inspectors. This document is known as INFCIRC/26, and after an amendment in 1965, it was introduced as INFCIRC/66 (IAEA, 2015; Alger, 2008).

When the Treaty on the Non-Proliferation of Nuclear Weapons came into force in 1970, conditions were created for the Agency to take "decisive" actions, which in 1971 led to the introduction of a new INFCIRC/153 inspection document, primarily introducing Comprehensive Safeguards Agreements (CSA). It defined the manner of cooperation between the Agency and the signatory states, especially non-nuclear-weapon states that have nuclear energy facilities for peaceful purposes. By signing the document, these states committed to Comprehensive Inspection Oversight by the IAEA on their territory and to provide inspectors with all information related to nuclear facilities and the use of radioactive materials in any area (IAEA, 2015; Alger, 2008).

Due to the Agency's inability, along with its inspectors, to respond to the challenges posed before it, there arose a need to introduce the Additional Protocol (INFCIRC/540) within the mechanisms implemented in order to respect the NPT. This Protocol expands the authorities of the Agency and its inspectors, granting greater rights to significant information and facilitating the detection of prohibited nuclear activities. The Additional Protocol was adopted in 1997 (IAEA, 2015).

Methods for detecting unauthorized activities

The inspection oversight system involves the application of various methods to detect and verify events that imply the occurrence of separation or any misuse of nuclear materials listed as prohibited and potentially usable for nuclear weapon production.

Materials of interest to inspectors are commonly referred to as special fissile materials. These usually include uranium isotopes 233 and 235, and plutonium-239. Some of these are naturally occurring, while others are artificially produced. For example, uranium-235 is found in small amounts in spent nuclear fuel. The process known as separation is used to obtain these isotopes of interest in a form necessary for the creation of the nuclear bomb core (IAEA, 2015). Separation is a complex and expensive method and has been a stumbling block for anyone attempting nuclear weapon production.

Each radioactive element leaves its unique signature on the environment when present. These are the traces used by nuclear forensics (Mayer et al, 2013; Ilić et al, 2022), to determine whether there has been production of a radioactive isotope, its use (López-Lora et al, 2023), or a nuclear test (Child & Hotchkis, 2013) in a particular space.

To detect the existence of these prohibited isotopes within a country's territory, inspectors utilize a range of methods, specifically detector tools that have significantly improved with technological advancements in recent years. Methods for detecting "special" fissile materials include: Environmental sampling for safeguards (ESS), Multi-channel analyzers (MCA), Alloy detectors (ALEX), Environmental monitoring instruments, Digital video surveillance systems, Satellite imagery, and Inspection Database (Donohue, 2002).

For uncovering unauthorized radioactive materials, the methods using environmental samples (ESS) include: High-resolution gamma spectrometry (HRGS), X-ray fluorescence spectrometry (XRF), Scanning electron microscopy electron/X-ray fluorescence spectrometry (SEM/XRF), Thermal ionization mass spectrometry (TIMS), and

Secondary ion mass spectrometry (SIMS). All these methods use dust samples collected from areas near the tested facility (Donohue, 2002).

Essentially, as almost all countries have agreed to the conditions of the Treaty on the Non-Proliferation of Nuclear Weapons, it is expected that the reports submitted by states are in line with the agreed-upon terms, and that no one would report nuclear activities prohibited by the Treaty, as they are committed otherwise. Thus, the inspector's role is to determine whether any signatory state is secretly pursuing nuclear program development. Inspectors effectively engage in accounting tasks, as they monitor the field's status and compare it with the reports from states and the records maintained by authorities overseeing nuclear facilities. In the past, numerous unauthorized activities were detected, but with the introduction of the Additional Protocol and reinforcement of other measures, they have significantly diminished. It is worth noting that participation in the Treaty and the Agency is voluntary, meaning the Agency lacks jurisdiction over territories of non-signatory or suspended states. A clear example is North Korea.

In addition to all these methods for monitoring the implementation of the Comprehensive Nuclear-Test-Ban Treaty, seismic methods are used to monitor ground tremors to identify those caused by nuclear tests (Sykes & Evernden, 1982). Various methods are also employed to avoid data manipulation and potential deception, which could undermine the regime and its effectiveness (He et al, 2021).

Discusions and conclusions

Since there are no absolute parameters determining the success of regimes, conclusions have to be drawn about their effectiveness from the available data, compared to projections related to the spread of nuclear weapons. Here, this part will deal with the number of nuclear warheads in the world, as well as with the conducted tests up to now. These two pieces of information are currently the only relevant parameters for evaluating the success of security regimes.

Estimating the number and trend of growth of nuclear warheads as a parameter of the effectiveness of the NPT

The current estimate of the number of warheads worldwide, through an overview of the status in individual states possessing this type of weaponry, is presented in the graph shown in Figure 1 (SIPRI, 2023). The total number of warheads has been decreasing for several years. This is primarily happening due to the United States of America and Russia, the

countries that are reducing their arsenals in accordance with bilateral agreements, as well as with their efforts to modernize their arsenals. Other nuclear powers are slightly increasing the number of nuclear warheads. Out of all, China stands out the most in this trend. In 2014, China had 250 nuclear warheads, but today, it possesses 410 warheads.

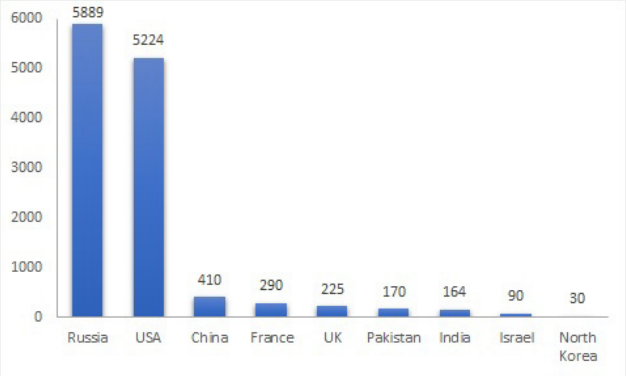

Figure 1 – Number of nuclear warheads per country today

The decreasing trend in the last 5 years is shown in the graph in Figure 2 (SIPRI, 2023).

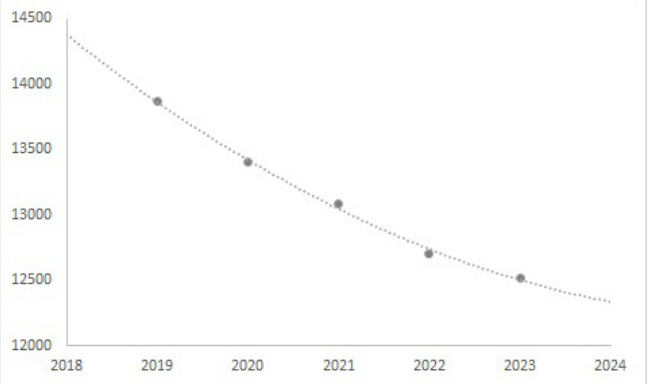

Figure 2 –Trend of decreasing the total number of nuclear warheads in the last 5 years (SIPRI, 2023)

The reduction trend for Russia and the USA was much more significant 10-15 years ago. Now, the decrease is occurring at a much

slower pace. This is likely influenced by the lack of trust and tensions that have persisted in the last few years (SIPRI, 2023).

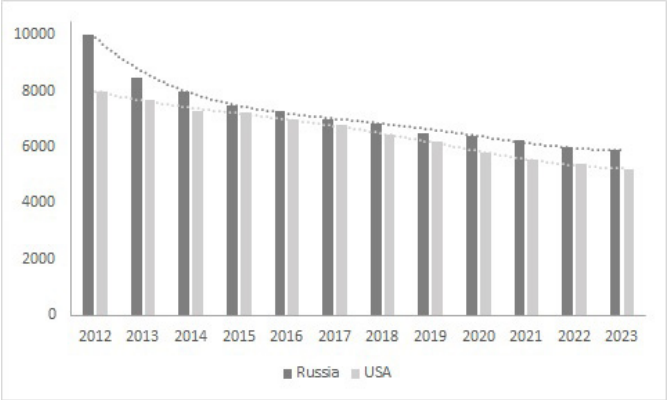

Figure 3 – Trend of reducing the number of warheads for Russia and the USA for period 2012-2023 (SIPRI, 2023)

Taking into consideration everything that has been mentioned, the impression arises that the regimes led by the NPT have not been particularly efficient in reducing nuclear armaments. However, considering that, at the time of the NPT's introduction, it was projected that by the year 1990, a total of 25-30 states would possess nuclear weapons (Carlson, 2005), today, over 20 years after that projected date, there are only 5 NWS along with an additional 4 states possessing nuclear warheads, most of which were on the brink of discovery. It is clear that the NPT, along with other regimes, has played a significant role in curbing the spread of nuclear weaponry.

Nuclear tests as an indicator of regime respect, foremost the CTBT

After World War II and throughout the Cold War era, nuclear weapons testing was a common practice to determine the effectiveness of specific weaponry and, likely even more so, to showcase power to other players participating in the race. There is indeed a vast number of studies, both older (Carter & Moghissi, 1977) and more recent ones (Gillies & Haylock, 2022), that address the impact of radionuclides resulting from nuclear tests on the natural world (Johansen et al, 2020; Prăvălie, 2014), as well as on humans specifically (Drozdovitch et al, 2021; Simon et al, 2006), not only

in terms of health but also concerning other essential factors that again influence human health deterioration (Riad et al, 2023) and the well-being of other living beings (Bouville, 2020).

To this day, over 2000 nuclear tests have been conducted, with the majority carried out by the United States of America (1032) and Russia (715). Most of these tests took place in the northern hemisphere of the Earth, while the number of nuclear tests in the southern hemisphere is almost negligible. This is somewhat expected, given that a significant portion of the southern hemisphere belongs to nuclear-free zones. In addition to the United States of America and Russia, nuclear tests were conducted by France (210), the United Kingdom (45), China (45), India (3), Pakistan (2), and North Korea (7). Other countries had some attempts at nuclear tests, but the only successful one was conducted in 1979. It took place in the Indian Ocean under the auspices of the governments of South Africa and Israel. After this event, South Africa abandoned its nuclear program. Although Israel has never been proven to possess nuclear weapons, it has unofficially been confirmed that the country holds a "serious" nuclear arsenal. The highest number of tests, a total of 178, was conducted in 1962 (Bergkvist & Ferm, 2000; United Nations, 2024).

Therefore, since the entry into force of the CTBT, 10 nuclear tests have been carried out. Of these 10, India and Pakistan each conducted two, while North Korea conducted 6 (United Nations, 2024). The tests by India and Pakistan are a result of their long-standing animosity. Specifically, these were the first two successful tests for Pakistan, and as India is in constant conflict with Pakistan, it also conducted two more tests (in addition to the one in 1974) to demonstrate its power. After these events, international pressure was exerted, and both India and Pakistan ceased testing, pledging to refrain from any form of nuclear weapon rattling. After 1998, only North Korea conducted tests in 2003, 2006, 2009, 2013, 2016, and 2017. The frequency of these tests diminished after 2017. A year earlier, North Korea successfully tested a thermonuclear bomb for the first time (Kristensen & Korda, 2022) . North Korea likely halted testing due to a combination of two factors: continuous UN pressure accompanied by sanctions and a relatively limited number of nuclear warheads (30) compared to other states possessing this type of weaponry.

Considering all of the above, it can be concluded that the CTBT is the most successful international security regime. However, the Agreement did not come about due to states' efforts to reduce the number of nuclear warheads worldwide but exclusively due to significant pressure from the scientific community, which recognized the harmfulness of tests and their impact on the environment (Carter & Moghissi, 1977).

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Regímenes de seguridad internacionales para prevenir la propagación de armamentos nucleares y su importancia global

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CAMPO: Ingeniería Nuclear
TIPO DE ARTÍCULO: artículo de revisión

Resumen:

Introducción/objetivo: El documento proporciona una visión general de los regímenes y acuerdos internacionales que tenían como objetivo detener la proliferación de armas nucleares. Para cada régimen, se presenta su impacto en la proliferación de armas nucleares, así como su importancia para detener las pruebas nucleares que representaban una amenaza de catástrofe ecológica global. Muchos de estos regímenes ya no están vigentes hoy, pero a lo largo de la historia desempeñaron su papel en el cumplimiento de necesidades específicas para detener la proliferación global de armas nucleares o de armas nucleares características de cierto alcance.

Métodos: El artículo analiza los acuerdos internacionales en este campo, así como los artículos en el campo de la seguridad nuclear procedentes de revistas de importancia internacional.

Resultados: El análisis de los regímenes de seguridad nuclear arrojó resultados que hablan de sus fortalezas y debilidades. La importancia y debilidades de los regímenes se dan a través del análisis y varios diagramas que muestran la tendencia al aumento de la cantidad de armas nucleares a lo largo del tiempo.

Conclusión: El trabajo señala la importancia histórica de los regímenes de seguridad nuclear, pero también sus debilidades, tanto en el pasado como en la actualidad. Está claro que estos regímenes suspendieron las armas nucleares, pero esta suspensión no condujo a la abolición completa de las armas nucleares, que es el objetivo final de los acuerdos.

Palabras claves: regímenes de seguridad, armas nucleares, proliferación, ensayos nucleares, acuerdos internacionales.

Режимы международной безопасности в предотвращении распространения ядерного оружия и их глобальное значение

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ВИД СТАТЬИ: обзорная статья

Резюме:

Введение/цель: В данной статье представлен обзор международных режимов и соглашений, цель которых заключается в прекращении распространения ядерного оружия. В статье представлено влияние каждого режима на распространение ядерного оружия, а также его значение в прекращении ядерных испытаний, которые представляли угрозу в виде глобальной экологической катастрофы. Многие из этих режимов сегодня уже не действуют, но на протяжении своей истории они играли важную роль в удовлетворении конкретных потребностей в прекращении глобального распространения ядерного оружия различного назначения.

Методы: Анализ международных соглашений в этой области, а также анализ статей в области ядерной безопасности из журналов международного значения.

Результаты: Анализ режимов ядерной безопасности дал результаты, выявляющие их сильные и слабые стороны. Значимость и недостатки режимов представлены путем анализа и нескольких диаграмм, которые показывают тенденцию роста и снижения общего количества ядерного оружия с течением времени.

Выводы: Данная статья освещает историческую важность режимов ядерной безопасности, а также показывает их недостатки как с исторической, так и с современной точки зрения. Более чем очевидно, что эти режимы остановили ядерное

вооружение. Однако это не привело к полной отмене ядерного оружия, что является конечной целью вышеуказанных соглашений.

Ключевые слова: режимы безопасности, ядерное оружие, распространение, ядерные испытания, международные соглашения.

Међународни безбедносни режими у спречавању ширења нуклеарног наоружања и њихов глобални значај

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Сажетак:

Увод/циљ: У раду је представљен преглед међународних режима и споразума који имају за циљ да зауставе ширење нуклеарног оружја. Приказан је утицај сваког режима на ширење нуклеарног оружја, као и његов значај у заустављању нуклеарних проба које су представљале претњу у смислу изазивања глобалне еколошке катастрофе. Многи од ових режима данас више нису на снази, али су током историје имали своју улогу у испуњавању специфичних потреба у заустављању глобалног ширења нуклеарног оружја или карактеристичног нуклеарног оружја одређеног домета. Методе: Анализирани су међународни уговори из ове области, као и текстови из области нуклеарне безбедности из часописа од међународног значаја.

Резултати: Анализа нуклеарних безбедносних режима дала је резултате који говоре о њиховој снази, односно слабостима. Значај и слабости режима приказани су кроз анализу и неколико дијаграма који показују тренд раста, односно пада укупног броја нуклеарних бојевих глава током времена.

Закључак: Рад указује на историјски значај нуклеарних безбедносних режима, али и на њихове слабости, како у ранијим временима, тако и данас. Јасно је да су ови режими зауставили нуклеарно наоружавање, али то није водило ка његовом потпуном укидању, што је крајњи циљ споразума.

Кључне речи: безбедносни режими, нуклеарно наоружање, ширење, нуклеарни тестови, међународни споразуми.

EDITORIAL NOTE: The second author of this article, Radovan V. Radovanović, is a current member of the Editorial Board of the *Military Technical Courier*. Therefore, the Editorial Team has ensured that the double blind reviewing process was even more transparent and more rigorous. The Team made additional effort to maintain the integrity of the review and to minimize any bias by having another associate editor handle the review procedure independently of the editor – author in a completely transparent process. The Editorial Team has taken special care that the referee did not recognize the author's identity, thus avoiding the conflict of interest.

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