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Artificial Intelligence, Nuclear Security, and the International Legal Framework

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About the VCDNP

The Vienna Center for Disarmament and Non-Proliferation (VCDNP) promotes international peace and security by conducting research, facilitating dialogue, and building capacity on nuclear non-proliferation and disarmament.

The VCDNP is an international non-governmental organisation, established in 2010 by the Federal Ministry for European and International Affairs of Austria and the James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies at Monterey.

Our research and analysis provide policy recommendations for decision-makers. We host public events and facilitate constructive, results-oriented dialogue among governments, multilateral institutions, and civil society. Through in-person courses and online resources on nuclear non-proliferation and disarmament, we train diplomats and practitioners working in Vienna and around the world.

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The IAEA headquarters at the Vienna International Centre, where States meet to discuss international nuclear security standards. Credit: IAEA.

Introduction

Rapid advances in artificial intelligence (AI) have alerted governments, companies, organisations, and the public to the benefits and potential threats of this technology. For the nuclear sector, the concern generally extends to nuclear security, nuclear safety, and non-proliferation, and has raised the question of whether the prevailing international legal framework is adequate as a basis for effective nuclear security, particularly given an expanding use of nuclear energy.

International efforts for nuclear security are related to the non-proliferation of nuclear weapons, recognising the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) as a landmark international treaty to prevent the spread of nuclear weapons and to promote cooperation in the peaceful uses of nuclear energy.

Nuclear security remains a solely national responsibility. The Convention on the Physical Protection of Nuclear Material (CPPNM) is, together with its 2005 Amendment, a centrepiece in the international legal framework for nuclear security. The CPPNM aligns with the four International Atomic Energy Agency (IAEA) nuclear safety conventions[1] in defining an approach for nuclear security and nuclear safety, respectively, and identifies important functions in a national system that is forecasted as a main tool to implement the conventions. The IAEA supports this process by offering a programme that includes services, guidance, peer reviews, and human resource development.

1 The Convention on Early Notification of a Nuclear Accident (Early Notification Convention) (1986), the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistance Convention) (1986), the Convention on Nuclear Safety (1996), and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (2001).

The nuclear security fundamentals published by the IAEA state:

Nuclear security focuses on the prevention of, detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities, or associated activities.[2]

The focus of this paper is the security of nuclear/radiological applications for peaceful purposes. The areas in which synergies between nuclear security and non-proliferation are recognised mainly relate to the physical protection of nuclear material in use, storage, and transport.

The paper examines areas in which AI may have an impact, negative or positive, on nuclear security and its legal instruments. The recommendations offered for discussion relate to the international legal framework for nuclear security and its implementation.

2 International Atomic Energy Agency, "Nuclear Security Fundamentals: Objective and Essential Elements of a State's Nuclear Security Regime," IAEA Nuclear Security Series, No. 20, 2013, Introduction, 1.1. Available at: STI/PUB/1590 ISBN 978–92–0–137810–1.

AI-driven risks, including malicious actors' enhanced ability to identify security gaps, must be considered in national and facility-specific threat assessments conducted by regulators and operators.

Emerging AI Capabilities and Relevance for Nuclear Security

Rapid advances in AI bring both benefits and challenges to the implementation of nuclear security. AI advances may provide positive contributions to the safe and secure operation of a nuclear facility, especially since AI capabilities could draw from larger datasets, offering a more comprehensive and broader perspective. At the same time, the potential use of AI by malicious actors could negatively impact the secure operations of a nuclear facility, especially if digital systems are compromised and intrusion is not detected. Contemporary implementation of effective nuclear security measures requires an understanding of recent AI developments and their potential influence on risk assessment, human behaviour, physical security, and the supply chain.

Areas of AI development that are particularly interesting for nuclear security are discussed below.[3]

3 Natasha Bajema, "Generative AI and WMD Nonproliferation: A Practical Primer for Policymakers and Diplomats", James Martin Center for Nonproliferation Studies, CNS Occasional Paper, No. 63, December 2024. Available at: https://nonproliferation.org/op63-generative-ai-and-wmd-nonproliferation-why-diplomats-and-policymakers-need-to-pay-attention-now-and-develop-ai-literacy/.

Access to Data

AI tools require access to huge amounts of data and a large amount of energy to process that data. Nuclear energy, for example, supplied by small modular reactors (SMRs) or large light-water reactors (LWR), has been identified as a possible solution to meeting the power demand driven by artificial intelligence.[4]

Relevance for Nuclear Security

- Access to credible data from a diversity of sources, e.g., in relation to the threat level, is central to effective nuclear security. Up-to-date information provides input for the basic design of the physical protection system and is a trigger factor for temporary upgrading that may be necessary because of a change in threat level. Access to credible information related to nuclear security is key for the effectiveness of the nuclear security system. A contemporary assessment of the threat, the timely follow-up of incidents (if any), technical protection measures, together with the required human readiness, constitute a solid basis for an effective nuclear security system. The Design Basis Threat (DBT) and information of events that may trigger temporary changes in the threat level are equally important.

- Site-related nuclear security information and technical measures are sensitive and contain datasets that must be kept confidential. This particularly relates to technical features of the physical protection system and to information that may be associated with individuals, e.g., as part of an ongoing criminal investigation or other law enforcement activities. While it is essential to maintain confidentiality of information, attention will be given to the necessity to share important information with the right target audience on a need-to-know basis. Incorrect or false information may find its way through the system and negatively affect the effectiveness of the security system implemented.

- Therefore, it is important that all information is (a) authenticated and (b) the digital software and hardware components of the nuclear security system remain unaffected by maliciously inserted software or manipulation of algorithms. The importance of credible and correct information is obvious and cannot be overstated.

Machine Learning

Machine learning is not new. Its definition by Arthur Samuel in 1959 described the field as giving computers "the ability to learn without being explicitly programmed".[5] Machine learning has contributed to recent advances in large language models, e.g., ChatGPT. New approaches to programming have built on machine learning by allowing models to create new data based on the data it was trained on in the first place. The models identify patterns, relationships, and statistical probabilities to generate their outputs. For machine learning models, programmers do not need to provide the computer with specific instructions on how to reach an output but rather inform the machine of the desired outputs and provide enough data, so the machine can develop its own rules.

Relevance for Nuclear Security

- The relevance of machine learning is the constant evolution and development of the abilities of IT systems. Vigilance to discover new features and abilities for software will be necessary, particularly for image recognition or in the use of biodata. The parallel development of, for example, image recognition and hacker skills to inject software into control systems may have the potential to reverse correct conclusions to incorrect ones.

4 The Google purchase of 10 SMR units and the Microsoft purchase of Three Mile Island for refurbishing and restart.

5 Abu Qais, "Introduction to Machine Learning", Medium, 8 June 2021. Available at : https://medium.com/analytics-vidhya/introduction-to-machine-learning-e1b9c055039c#:~:text=According%20to%20Arthur%20Samuel(1959)%20%3A%20Machine%20learning%20is%20a,automatically%20improve%20with%20the%20experience.

Predictive AI

Predictive AI includes powerful AI systems that have been deployed in the past decade, including specialised tools that exceed human capabilities on specific, well-defined tasks. These functions may help the understanding and formulation of complex relationships, providing higher confidence in the results obtained from statistical and other data.

Predictive AI methodologies depend on the availability of datasets that are relevant for the problem defined. With abundant datasets to feed the methodology as source data, the preciseness of the results may be obtained and, in some cases, give valuable contributions. With insufficient datasets or lack of authentication of the data, the results will become unreliable. This is an important consideration in the security domain since background information, either from the nuclear sector or law enforcement, is often confidential and not shared with a broader audience.

Relevance for Nuclear Security

- **Increased information precision:** Generally, predictive AI may develop as an important tool for nuclear security to strengthen the nuclear security system or identify nuclear security vulnerabilities. In the same manner, AI tools could impact outputs and alter correct conclusions to incorrect ones, e.g., in the identification of persons through biodata.

- **Calculation of radiological consequences:** The reactor core content of radioactive isotopes (fission products) is the source data for estimates or calculations of dispersal scenarios and the calculation of the radiological consequences that may be the result of different circumstances.

- I**mproved image recognition:** Another positive application is image recognition, which may be of critical value for access control. This could help ensure that only authorised personnel can access a nuclear facility or flag when non-authorised personnel are detected.

- **Estimation of delay times:** Negative applications of predictive AI may include calculation of potential delay times, giving perpetrators information of response times and "safe" operating times as well as advanced estimates of the potential risk of detection of theft of nuclear material, or of sealed radioactive sources. This information could also facilitate a malicious actor's attempt to compromise a facility's security system by hacking into the digital systems of a facility and compromising software used in the control systems.

Generative AI

Generative AI is defined as tools "to produce new data that is similar to a given dataset".[6] In contrast to predictive AI tools, generative AI produces new, similar outputs by extending patterns or rules beyond the original training data. Generative AI models are referred to as "probabilistic rather than deterministic", with unlimited possibilities to generate novel outputs.[7] This is both a strength and weakness of generative AI, as it offers a limitation in the accuracy of answers or facts while also introducing an element of randomness. In other words, the output may be completely "made-up" without connection to reality. Generative AI tools include large language models, e.g., ChatGPT, text-to-image generators, and music and video generation. Generative AI may also provide synthetic data to improve capacities of machine learning models and generate new software codes or algorithms.

6 David Foster, "Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play," Second Edition, (Boston, MA: O'Reilly Media, Inc., 2023), p. 4.

7 Ibid.

Relevance for Nuclear Security

- **Access control:** Generative AI tools may be used to aid a perpetrator in obtaining authorisation to enter a facility or location, or to access a digital security system. Persons that are not authorised to access a protected area could possibly be accepted, based on false information, including biodata. The potential for a security system to recognise such false data may be directly relevant for its effectiveness.

- **Design Basis Threat (DBT):** The design of the security system is normally based on a national and local threat assessment which brings together information of the prevailing threat and potential consequences. The establishment of the DBT is normally a national responsibility, in which national organisations are assigned to contribute to the assessment within their mandate. Related information will, therefore, be provided from a variety of sources. Should false data be used in the assessment, the threat estimate may also be compromised.

- **Compliance with physical protection requirements:** Incorrect descriptions and false images and reports will contribute negatively to the security robustness of a nuclear facility. Personnel information may also be compromised, including data, images, and biodata. Personal data in the wrong hands may be a direct security risk.

Advances in Hardware Capacities

The role of hardware for AI is both fundamental and multifaceted. Understanding the different components and how they affect different aspects of AI computation, e.g., the processor speed memory and storage, as well as the overall system's design, such as its cooling capacity and power delivery, will help identify potential areas in which AI may become a new threat that could impact the effective implementation of nuclear security.

The impact of powerful new hardware in the process control applied in nuclear facilities must be considered in the establishment and implementation of nuclear security, particularly in relation to the assessment of consequences, radiological or other, of a potential security event.

AI Evolution and Nuclear Security

The evolution of software, algorithms, processors, and memory capacity has been faster than originally expected and will, most likely, continue along this development path.

The possibility of constructing an unmanned vehicle or drone that would be able to enter a nuclear facility or a location where a radiation unit is operating, has been described as a "new" threat, one that may have considerable relevance for the threat assessment at a nuclear facility. Such an item would have to combine several advanced features and capabilities. It is perceived as a major challenge for even a small group of human perpetrators to reach a vital area in a nuclear facility to perform an act of sabotage that would cause a release and dispersal of radioactive substances. The ability of an unmanned, remotely operated vehicle or drone to perform the sequence of actions that would be required to enter a security area of a nuclear facility appears overwhelming. The anticipated scenario would project an unmanned item to pass through several checkpoints, some possibly protected as vital areas, to finally reach the target point. Such a scenario will have to be closely evaluated to understand the timeline in which an unmanned vehicle could defeat, if at all, security barriers in place.

The 2022 Review Conference of the Convention on the Physical Protection of Nuclear Material and its Amendment (A/CPPNM). Credit: IAEA/Dean Calma.

The International Legal Framework Governing Nuclear Security

The international legal framework for nuclear security and non-proliferation has evolved incrementally since the US Atoms for Peace initiative was presented by President Eisenhower in 1957. The initiative turned attention from the proliferation of nuclear weapons and their massive destruction potential to the peaceful uses of atomic energy for development. The IAEA was established as a result of President Eisenhower's speech, mandated through its statute under Article II "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world", and to "ensure, so far as it is able, that assistance provided by it or under its supervision or control is not used in a way as to further any military purpose."[8]

Non-proliferation and nuclear security are two sectors with international undertakings that are often referred to as having synergies and common goals. However, these are two sectors with different objectives: non-proliferation, on the one hand, aims to prevent the proliferation of nuclear weapons by States, whereas nuclear security, on the other hand, aims to protect nuclear material and facilities in peaceful applications from criminals or terrorists. The overarching goal is to prevent nuclear material from causing explosions or other radioactive events.

8 International Atomic Energy Agency, "The Statute of the IAEA", 1957, Article II. Available at: https://www.iaea.org/about/statute#a1-2.

The activities and measures to reach this goal are different. The IAEA has stated:

The synergies between non-proliferation and physical protection were first illustrated when, in the context of the 1975 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the States Parties adopted a Declaration, on 30 May 1975, in which they urged the further elaboration of concrete measures for the physical protection of nuclear material in use, storage and transport. The contribution of enhanced physical protection to the prevention of theft, vandalism, sabotage and terrorism was explicitly confirmed in General Conference resolution GC(XIX)/RES/328 of 26 September 1975.[9]

Since then, a major evolution in these two areas has taken place.

It must be noted that there is a fundamental difference in the role of the IAEA in non-proliferation and nuclear security. While the IAEA *verifies the continued peaceful uses* of nuclear material in accordance with safeguards agreements concluded between the State and the IAEA, its role for nuclear security is to *provide services*, as requested by States. In both areas, the IAEA implements a programme approved by its Member States, with established approaches, information, supporting activities, and human interaction.

Recent AI advances may have an impact on the implementation of IAEA programmes by enhanced access to or increased capacity of processing information, which may contribute positively to the Agency's ability to carry out its programmes.

The following section provides an overview of the legal foundation for nuclear security. This foundation is further associated with non-proliferation and humanitarian law. However, this is not covered in this paper.

The International Legal Foundation for Nuclear Security

In the early 1970s, the establishment and operation of physical protection systems for nuclear material and facilities were entirely a matter for the individual State. Since then, there has been a growing recognition of the need for cooperation among States to ensure the physical protection of nuclear material against theft or unauthorised removal, especially during international transport, and against the sabotage of nuclear facilities. Initially, most attention was given to theft of vulnerable nuclear material, i.e., highly enriched uranium (HEU) and plutonium.[10] Later, the concern of dispersal of radioactivity emerged, and the need to protect nuclear material, facilities, and transports from acts of sabotage was added. The present international legal framework for nuclear security covers these threats.

The international legal framework comprises a core of binding undertakings in conventions, in UN resolutions, and other agreements.[11] They are referred to as *primary legal instruments* since the undertakings are legally binding and need to be reflected in national law. International conventions or treaties may be developed and negotiated under the auspices of the IAEA, the UN, or other international organisations. In all, there are 19 international counterterrorism instruments.[12] The body of law that comes from the principles and objectives of treaties is known as *secondary law* and includes regulations, directives, decisions, recommendations, and opinions. For nuclear security, the IAEA provides guidance, published in the IAEA Nuclear Security Series (NSS), for the implementation of practical, national nuclear security systems, which may be designed to fit the circumstances in an individual State. IAEA guidance is both independent of and compliant with commitments made by the State Parties in conventions.

9 International Atomic Energy Agency, "The International Legal Framework for Nuclear Security", IAEA International Law Series, No. 4, 2011, p. 3. Available at: STI/PUB/1486 ISBN 978–92–0–111810–3.

10 Vulnerable nuclear material is defined as Category I nuclear material in the Convention of Physical Protection of Nuclear Material.

11 International Atomic Energy Agency, "The International Legal Framework for Nuclear Security," IAEA International Law Series, No. 4, 2011.

12 UN Office of Counter-Terrorism, International Legal Instruments, International Legal Instruments. Available at: https://www.un.org/counterterrorism/international-legal-instruments.

The core conventions and resolutions that constitute the international legal foundation for nuclear security are:

The Convention on the Physical Protection of Nuclear Material and its Amendment

Since the early 1970s, recognition grew among States of the need to cooperate to ensure that a reasonable and effective level of physical protection is applied to nuclear material against theft or unauthorised removal, especially during international transport. This recognition underlined that the establishment and operation of physical protection systems for nuclear material and facilities were entirely the responsibility of each State. In 1977, an Advisory Group of Member States' representatives recommended that a formal process should be initiated by the IAEA to elaborate a Convention on the Physical Protection of Nuclear Material (CPPNM). The IAEA initiated the recommended process and the developed CPPNM was adopted on 26 October 1979, opened for signature on 3 March 1980, and entered into force on 8 February 1987.

The CPPNM establishes legal obligations for the Parties regarding the physical protection of nuclear material used for peaceful purposes during international transport, the criminalisation of defined offences involving nuclear material, and international cooperation, for example, in the case of theft, robbery, or any other unlawful taking of nuclear material or credible threat thereof. As the basis for the obligations to protect nuclear material in international transport, the CPPNM defines categories of nuclear material, based on its attractiveness for the making of explosive devices. This categorisation is maintained in all subsequent international agreements, in the Nuclear Suppliers Group (NSG) Guidelines, and in the IAEA nuclear security guidance documents. In the CPPNM, the obligations for physical protection of nuclear material are limited to international transport, as defined in Articles 3, 4, and paragraph 3 of Article 5. All other articles have general applicability, e.g., Article 5, paragraphs 1 and 2 relate to information exchange and cooperation among State Parties and with the IAEA, Article 6 with the requirement for State Parties to "take appropriate measures consistent with their national law to protect the confidentiality of any information which they receive in confidence by virtue of the provisions of this Convention", or Article 7 that defines the acts that shall be made punishable offences by each State Party under national law.

In 1999, a process to strengthen the CPPNM began. State Parties had become aware of the absence of international obligations related to the physical protection of nuclear material in domestic use, storage, and transport. After five years of development, an Amendment to the CPPNM was approved in 2005. The CPPNM, together with its Amendment, became a solid foundation for physical protection and other security arrangements for nuclear material. The scope of the Convention and its Amendment does not include radioactive substances that are not mixed with nuclear material, such as sealed radioactive sources.

The Amendment presents 12 fundamental principles for a national nuclear security system to be implemented by the State Parties. The Amendment indicates that a graded approach may be taken for the national nuclear security system, depending on the nuclear activities and nuclear material in the country. The fundamental principles as well as other undertakings shall apply insofar as is reasonable and practicable. This introduces some flexibility, in recognition of the physical properties of the nuclear material or nuclear facilities in each country, as well as local variations in the prevailing threat.

Fundamental principles A-E relate to the allocation of responsibilities, first at the level of the State for the national implementation of the requirements of the Amendment and for the transfer of responsibility of an international nuclear transport. The responsibilities of the State include the establishment of a legislative and regulatory framework and a competent authority. However, the prime responsibility to ensure effective implementation of physical protection at the nuclear facility or for the nuclear material rests with the licence holder.

Fundamental principles F-L relate to the elements of the national nuclear security system. These principles underline the importance of a security culture to ensure the effectiveness of the nuclear security system, and that the State's physical protection should be based on its evaluation of the threat.

In meeting the threat, a graded approach should be applied, with measures that are based on the principle of defence in depth, i.e., several layers of protection. Other principles communicate the necessity of having a quality assurance policy, contingency plans, and the need to protect sensitive information as confidential.

The CPPNM and its Amendment highlight, in several articles, the obligation for the Parties to cooperate, through information exchange, with assistance, and active interaction. This extends to the international organisations that have nuclear security responsibilities, primarily the IAEA.

The CPPNM has 165 State Parties and the Amendment 137 State Parties. Still, 28 States that are State Parties to the CPPNM have not ratified the Amendment. That step is necessary for the obligations to become universal. When all State Parties to the CPPNM have ratified the Amendment, the name of the combined convention will become the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities (CPPNMNF).

AI and the CPPNM and its Amendment

The CPPNM and its Amendment do not contain any articles or preambular paragraphs that relate to specific threat scenarios. Each State Party will evaluate the prevailing threat, assessing what is relevant for them, based on available information. AI may assist in the collection and analysis of new or additional information that may be helpful in the threat assessment and in determining any updates needed to the threat assessment. However, unless AI-provided information is authenticated, incorrect or false information may unintentionally, or intentionally, contribute to the evaluation. The CPPNM and its Amendment do not include specific requirements for IT security. However, if digital applications are used at a nuclear facility, protecting those systems against potential threats would be part of the implementation process. For example, the use of AI tools to alter or incapacitate digital control systems is a potential threat that would need to be protected against. Other possible threats include the potential for AI tools to contribute incorrect or false information in digital systems resulting in inaccurate outputs (whether intentional or not), and the insertion of malicious software to manipulate digital systems outputs.

In particular, fundamental principles G; Threat, I; Defence in Depth, and J; Quality assurance, underline the need for and importance of including the possible use of AI technologies in nuclear facilities, both for benign and potential malicious purposes, when implementing the CPPNM and its Amendment.

The protection against potential threats within nuclear facilities associated with the use of AI applications must be considered when assessing the overall security system. Therefore, these technical developments, applications, and their control are covered under the implementation of the CPPNM and its Amendment.

The Early Notificiation and Assistance Conventions

The Convention on the Early Notification of a Nuclear Accident (Early Notification Convention) and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergeny (Assistance Convention) were adopted at a special session on 26 September 1986, in the same year as the Chernobyl accident occurred. The international community recognised the absence of information regarding the occurrence of a nuclear event that resulted or may result in the release of radioactive substances as a major gap. It was also recognised that the remediation of radiological consequences may require resources not available in all countries, and that countries would benefit from an international legal instrument that facilitates mutual assistance. As a result, IAEA Member States urgently initiated and completed a process to develop and approve the two new conventions.

The Early Notification Convention covers all nuclear materials, any reactor or nuclear fuel cycle facility, as well as any radioisotope used for any nuclear or non-nuclear purposes. The major undertaking in the Convention is to notify, directly and through the IAEA, those States which are or may be physically affected by a nuclear accident or any other event to minimise any radiological consequences. In this regard, a security event would be looked upon as a nuclear accident and be subject to notification as forecasted in the Early Notification Convention.

The Early Notification Convention entered into force on 27 October 1986 and the Assistance Convention entered into force on 26 February 1987, less than one year after the Chernobyl accident. While conceived and adopted as safety instruments, the Early Notification and Assistance Conventions strengthen the international response to nuclear accidents or radiological emergencies, irrespective of the cause of the event, i.e., including a security event that caused or may cause the release of radioisotopes. The Early Notification Convention has 134 Parties; the Assistance Convention has 129 Parties.

AI and the Early Notification and Assistance Conventions

These Conventions identify legal obligations regarding the exchange of information, the provision of assistance by and interaction among the Parties. It is understood that information submitted by a Party regarding a nuclear accident or a security event is correct, as far as possible, under the prevailing circumstances. With time, new or supplementary information will be added. The IAEA is identified as a recipient of the information provided and has an obligation to distribute the information among the Parties to the Conventions.

AI tools may be used to gather and assess a wide range of sources of information and could contribute to a fuller understanding of the accident and the related circumstances. Thereby, AI functions may help in the evaluation of the accident, its cause, and consequences, including the potential of dispersal of radioisotopes. On the other hand, the possibility of providing incorrect or false information, potentially to negatively impact the analysis and intentionally move the conclusions in a different direction, must also be recognised. The need to authenticate information emerges as a vital part of the process.

IAEA Guidance to Implement Effective Nuclear Security

The IAEA establishes and maintains the Nuclear Security Series (NSS) as part of its central role in providing nuclear security-related international support and coordination. The nuclear security guidance documents developed and published in the NSS are reviewed and approved by a Nuclear Security Guidance Committee (NSGC) in an open-ended process. The nuclear security guidance is voluntary for States to implement, as are the IAEA nuclear safety standards.

The Nuclear Security Series was launched in 2006, has produced 48 guidance documents, and is continuously updated. The top-tier document, "Nuclear Security Fundamentals", was approved by the IAEA Board of Governors in 2012.[13] The series is structured in four sets of publications:

- **Nuclear Security Fundamentals**, which establish the fundamental objective and essential elements of a State's national nuclear security regime.
- **Recommendations**, which set out measures that States should take in order to achieve and maintain an effective regime.
- **Implementing Guides**, which provide guidance on how States can implement the recommendations.
- **Technical Guidance**, which provide more detailed guidance on specific methodologies and techniques for implementing security measures.

Three guidance documents have been published for IT and computer security: NSS No. 17-T (Rev.1) Computer Security Techniques for Nuclear Facilities (2021); NSS No. 42-G Computer Security for Nuclear Security (2021); and NSS No. 17 Computer Security at Nuclear Facilities (2011).

13 IAEA, Nuclear Security Series, "Resources". Available at: https://www.iaea.org/resources/nuclear-security-series#:~:text=Nuclear%20Security%20Fundamentals%2C%20which%20establish,and%20maintain%20an%20effective%20regime.

The guidance documents address computer security in general and at nuclear facilities. Detailed guidance is given on developing, implementing, and integrating computer security as a key component of nuclear security and its management. It further addresses interfaces with nuclear safety and other elements of the nuclear security regime established in an individual State.

AI aspects, whether to strengthen nuclear security analysis, assessment of risks, or potential abuse or misuse of AI systems are not addressed specifically. The IAEA, however, is giving considerable attention to AI development and its potential impact on nuclear security.

Primary Legal Instruments Developed Under the Auspices of the United Nations

In December 1996, the UN established an Ad Hoc Committee for the purpose of elaborating on legal instruments for the prevention, suppression, and elimination of terrorism in all its forms and manifestations.[14] The specific mandate of the Ad Hoc Committee was to establish "an international convention for the suppression of terrorist bombings and, subsequently, an international convention for the suppression of acts of nuclear terrorism, to supplement related existing international instruments, and thereafter to address means of further developing a comprehensive legal framework of conventions dealing with international terrorism."[15]

The UN Security Council may adopt resolutions under Chapter VII of the UN Charter, which makes the resolutions binding on all States. There are two UN Security Council resolutions (UNSCR) that are directly relevant to nuclear security and refer to the IAEA, both of which are discussed in more detail below: UNSCR 1373 (2001) and UNSCR 1540 (2004). Although the IAEA did not participate in the development of these resolutions, the IAEA Board of Governors recognised the resolutions as integral parts of the legal framework for nuclear security and referred to them as such in the IAEA Nuclear Security Plan for 2006-2009.

The International Convention for the Suppression of Terrorist Bombings

The objective of the International Convention for the Suppression of Terrorist Bombings (the Terrorist Bombings Convention)[16] is to enhance international cooperation among States in devising and adopting effective and practical measures for the prevention of acts of terrorism, and for the prosecution and punishment of their perpetrators.[17] The Terrorist Bombings Convention creates a regime of universal jurisdiction over the unlawful and intentional use of, or attempts to use, explosives and other lethal devices in public places with intent to kill or cause serious bodily injury, or extensive destruction through the release or dispersal of toxic chemicals, biological agents, toxins, or radioactive material. If a State Party receives information that a person has or is alleged to commit an offence as identified in the Convention, it is obliged to take measures to investigate the facts contained in the information.

The Convention, which entered into force on 23 May 2001, has 170 State Parties.

AI and the Terrorist Bombings Convention

AI tools may be used to collect and assess information from a wide range of sources, thereby contributing to the evaluation of the correctness of information received according to Article 7 of the Convention. The importance of correctness of information becomes clear in any such case, as any added information, if incorrect or false, could result in an incorrect evaluation.

14 UN General Assembly, 51st Session, Resolution 51/210, 1996. Available at: https://docs.un.org/en/A/RES/51/210.

15 UN General Assembly, Sixth Committee (Legal), 62nd session, "Summary of Work". Available at: https://www.un.org/en/ga/sixth/62/Terrorism.shtml.

16 International Convention for the Suppression of Terrorist Bombings, 23 May 2001. Available at: https://treaties.un.org/doc/db/terrorism/english-18-9.pdf.

17 UN Special Treaty Event for the Promotion of Universal Counter-Terrorism and Crimes Conventions and the Convention on the Safety of United Nations and Associated Personnel, 20 April 2009, Vienna, Austria.

The International Convention for the Suppression of Acts of Nuclear Terrorism

The International Convention for the Suppression of Acts of Nuclear Terrorism (the Nuclear Terrorism Convention)[18] has a broader scope than the CPPNM and its Amendment by its criminalisation of acts involving "radioactive material", which includes not only nuclear material, but also other radioactive materials, as defined in the Convention.[19] It also brings under its scope nuclear material and facilities used or retained for military purposes, which are explicitly excluded from the scope of the CPPNM and its 2005 Amendment. The Nuclear Terrorism Convention is primarily an international criminal law instrument that defines certain acts as criminal offences and obliges State Parties to establish their jurisdiction over such offences, to render them punishable under domestic law, and to provide for the extradition or prosecution of alleged offenders under the principle of *aut dedere aut judicare* (extradite or prosecute). The preambular paragraphs recognise the CPPNM and the operative paragraphs recognise the IAEA as the competent international organisation for radioactive substances, including nuclear materials, in peaceful uses. Physical protection is recognised to protect radioactive materials, facilities, and devices from theft or other malicious acts.

State Parties shall make every effort to ensure the protection of radioactive material, thereby taking into account relevant IAEA recommendations and functions. Upon seizing of radioactive material following the commission of an offence defined in the Convention, the State Party shall take steps to render harmless the radioactive material and ensure that safeguards are applied and that physical protection recommendations and health and safety standards published by the IAEA are maintained.

Brought together conceptually, the CPPNM, its Amendment, and the Nuclear Terrorism Convention constitute a very solid foundation for nuclear security. It is noted that the exchange of information among States and international organisations is necessary and useful for effective implementation. Both legal instruments require that sensitive information is protected against unauthorised sharing or use.

UN Security Council Resolution 1373 (2001)

On 28 September 2001, the Security Council unanimously adopted UNSCR 1373 as one of several steps to put in place wide-ranging, comprehensive strategies to combat international terrorism. It is focused on the financing of terrorist acts. The resolution underlines the interaction among Parties to find ways of intensifying and accelerating the exchange of operational information, especially regarding:

- Actions or movements of terrorist persons or networks;
- Forged or falsified travel documents;
- Trafficking of arms, explosives, or sensitive materials;
- Use of communication technologies by terrorist groups; and
- The threat posed by the possession of weapons of mass destruction by terrorist groups.

The resolution calls upon States to report to the UN Committee established by the Security Council to monitor implementation of the resolution.

18 The International Convention for the Suppression of Acts of Nuclear Terrorism, 13 April 2005. Available at: https://treaties.un.org/doc/Treaties/2005/04/20050413%2004-02%20PM/Ch_XVIII_15p.pdf.

19 International Atomic Energy Agency, "The International Legal Framework for Nuclear Security", IAEA International Law Series, No. 4, 2011, p.5.

UN Security Council Resolution 1540 (2004)

In connection with the continuous efforts by the Security Council to elaborate a comprehensive counter-terrorism regime, the Council unanimously adopted UNSCR 1540 on 28 April 2004, obliging all States to refrain from supporting non-State actors that attempt to develop, acquire, manufacture, possess, transport, transfer, or use nuclear, chemical or biological weapons, and their means of delivery. The resolution refers to weapons of mass destruction, delivery systems, and "related materials", and obliges States to protect their nuclear material by adopting and enforcing national legislation (laws and directives) that prohibit non-State actors from acquiring nuclear material. The resolution obliges States to account for and secure such items, exercise national control, and provide effective physical protection.

The IAEA is referred to regarding its responsibilities and assistance provided through its programmes. The Resolution does not impact on other legal undertakings, e.g., made in other conventions or bilateral agreements.

Relevance of UNSC Resolutions for Nuclear Security

Implementation of UN Security Council resolutions adopted under Chapter VII of the UN Charter is legally binding for all UN Member States. UNSCR 1373 (2001) and UNSCR 1540 (2004) are seen as particularly important for nuclear security, as defined by the IAEA, inter alia, because of the contained references to IAEA programmes and responsibilities. The UNSC resolutions, the conventions, and other agreements contribute to a global arrangement of measures, information, and interactive groups of States and organisations that recognise the same fundamental elements in a nuclear security system. The exchange of information and its evaluation and follow-up actions may benefit from access to AI technologies, provided the information is correct and reliable.

Primary Legal Instruments Developed under the Auspices of the IMO

Some of the legal instruments established under the auspices of the International Maritime Organization (IMO) are relevant for nuclear security, be it the criminalisation of identified offences or the control and care of nuclear or other radioactive materials on board or at fixed platforms. These legal instruments are:

- The Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (1988 SUA Convention)[20]
- The Protocol for the Suppression of Unlawful Acts against the Safety of Fixed Platforms Located on the Continental Shelf, Rome, 1988 (1988 Fixed Platforms Protocol)
- The 2005 Protocol to the SUA Convention
- The 2005 Protocol to the Fixed Platforms Protocol

The main purpose of the SUA Convention and related Protocols is to suppress unlawful acts against ships and fixed platforms and to ensure that appropriate actions are taken against alleged perpetrators. In 2005, the 1988 SUA Convention and the 1988 Fixed Platforms Protocol were each updated with two separate Protocols to ensure that the maritime security framework was capable of responding to contemporary threats. The 2005 Protocols were agreed after three years of negotiation and in consideration of UNSCR 1540.

The Protocols introduce new offences that State Parties are obliged to criminalise, i.e., acts carried out with the intent to intimidate a population, a government, or an international organisation to do or to abstain from doing any act (including illicit trafficking), using any explosive, radioactive material, or biological, chemical, or nuclear weapon in a manner that causes or is likely to cause death or serious injury or damage.[21]

20 International Maritime Organization, International Conference on the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA)", March 1988. Available at: https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/Pages/SUA.aspx.

21 Protocol of 2005 to the Protocol for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms Located on the Continental Shelf, Article 4, Article 2bis. Available at: Protocol_to_Fixed_Platform_Protocol_E.pdf.

Thereby, the scope of the SUA Convention and the Fixed Platform Protocol from 1988 and 2005 cover the same materials, substances, or items defined in the Conventions and Resolutions referred to in sections 3.1 and 3.2. This provides a common foundation of acts that are defined as criminal offences. Further, this platform of conventions and resolutions indicates, in various ways depending on the specific convention, that State Parties are obligated to apply a set of measures to keep radioactive substances and nuclear materials secure, whether in use, process, or storage, and to treat any acts that are defined as criminal offences accordingly.

AI and IMO International Legal Instruments

The threats that may be identified for transportation of radioactive substances or nuclear material at sea or at fixed platforms are similar to those that are referred to in other nuclear security conventions or resolutions. The 1988 SUA Convention and related Protocols from 1988 and 2005 underline the key value of State Parties interaction, directly and through information exchange. The increased capacities of AI may contribute positively to that process, with the recognition that information submitted and exchanged must be correct and authenticated. If not, the use of AI could inadvertently have a negative impact.

The Legal Foundation to Maintaining Nuclear Material and Facilities in Peaceful Uses

The NPT entered into force in 1970 and was extended indefinitely in 1995. The key objective of the Treaty is to prevent the proliferation of nuclear weapons while maintaining access to nuclear technologies and materials for peaceful purposes. The conclusion of safeguards agreements with the IAEA for non-nuclear weapon States (NNWS) is an NPT obligation. The safeguards agreements are comprehensive and provide that the State establishes and maintains "a system of accounting for and control of all nuclear material subject to safeguards under the Agreement."[22] Thereby, a State will have a record of its nuclear material, its form, quantity, and location, all of which is information required to establish the necessary physical protection measures.

A voluntary mechanism to limit exports of nuclear materials and technology only to States that is Party to the NPT or similar treaty has evolved over the past decades with the establishment of the Nuclear Suppliers Group (NSG). The NSG maintains lists of materials and technology and guidelines for the process under which export of these items may take place. The guidelines include a requirement that nuclear materials and facilities shall be subject to physical protection, according to IAEA recommendations. Many States have adopted the NSG guidelines as their national requirements to issue an export licence.

The Interface Between Nuclear Security and Nuclear Safety

Nuclear safety and security are both fundamental objectives in the management of nuclear power and in other activities involving nuclear and other radioactive materials. In April 2023, the IAEA published a joint report of the Advisory Group on Nuclear Security (AdSec) and the International Nuclear Safety Advisory Group (INSAG), identifying commonalities and differences between nuclear security and safety, with a view to stimulate new thinking on how common elements can enhance effectiveness in the management of nuclear activities.[23] The common objective of both nuclear safety and security – namely, to protect people, society, and the environment from unwanted radiation – promotes a synergistic perspective by which nuclear safety and security can be viewed and enhanced. It draws on a recognition of the increasingly rapid pace of technology development and the need for the nuclear and radiological industries to respond to new challenges and demands.

22 International Atomic Energy Agency, "The Structure and Content of Agreements between the Agency and the States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons", INFCIRC/153 (Corrected), Paragraph 7. Available at: https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf.

23 IAEA, "A Systems View of Nuclear Security and Nuclear Safety: Identifying Interfaces and Building Synergies", AdSec/INSAG, Report No. 1, 2023. Available at: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB2037_web.pdf.

The report outlines areas of particular interest in the implementation of nuclear safety, nuclear security, and their interfaces. These areas include the nuclear safety standards and the nuclear security guidance, the coordination in and of international activities, e.g., conferences and peer reviews, and the use of safety assessment techniques to evaluate nuclear security protection and computer/IT security.

Sustainable human resource development was pointed to as an important area for nuclear safety and security, recognising both differences and commonalities in the approaches to human resource development. Finally, the report points to a need to broadly increase the understanding of nuclear safety and security and encourages the exchange of more non-sensitive information.

AI techniques could facilitate the understanding of both nuclear safety and nuclear security, clarifying the background and commonalities in the parameters that are important for both. This understanding appears vital in the assessment of consequences for acts of theft, sabotage, and radiological events. However, information must be trustworthy, correct, and possible to authenticate. Otherwise, there is an increased risk that nuclear security arrangements may become less effective.

Standards set in collaboration between industry, governments, international organisations, and civil society will play a key role in reining in the nuclear security risks posed by AI.

International (Industry) Standards

AI technology is already used in a multitude of applications, for example, in software, equipment, and for improved analysis. AI development is driven by industry and customer demands. Likewise, the need for a standardised approach in establishing, implementing, and improving AI technology is internationally recognised. Such standards are predominantly developed by the civil sector standards organisations, in which industry, academia, governmental, and non-governmental organisations are represented. Implementation of international, industry standards is voluntary and agreed upon, inter alia, by the manufacturer of the equipment or services. Compliance with these international standards is certified by an established and accredited test-house.

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are the two main organisations that develop and publish standards that are used in the manufacturing of goods and in the offering of services.[24] The objective and goal of international standards is to ensure that the products and services are safe, reliable, and of high quality. Standards may provide technical targets, e.g., tolerances in measurements or constructions, or provide guidance for sustainable and ethical practices that may be used in industrial applications.

The IEC addresses and develops standards that are applied to electrotechnical equipment and ISO provides international standards that may be applied to industrial and management processes.

24 International Organization for Standardization, "Artificial intelligence: What it is, how it works and why it matters". Available at: https://www.iso.org/artificial-intelligence.

Both organisations are made up of national bodies, which are members of the organisation. Several Technical Committees are defined in which the standards are developed. ISO and IEC collaborate in fields of mutual interest; one such area is the development of joint standards for AI. Factors influencing the many use cases for AI include the need to strike the appropriate balance between governance mechanisms and innovation. Other international organisations, governmental and non-governmental, in liaison with ISO and IEC, may take part in the work.

Eight ISO/IEC joint international standards have been developed and published, others are under development:

- ISO/IEC 42001:2023, AI management systems
- ISO/IEC 23894:2023, AI – Guidance on risk management
- ISO/IEC 23053:2022, Framework for AI systems using machine learning
- ISO/IEC 38507:2022, Information technology – Governance of IT – Governance implications of the use of artificial intelligence by organizations
- ISO/IEC TR 24027:2021, Information technology – Artificial intelligence (AI) – Bias in AI systems and AI aided decision making
- ISO/IEC TR 24029-1:2021, Artificial Intelligence (AI) – Assessment of the robustness of neural networks – Part 1: Overview
- ISO/IEC TR 5469, Artificial intelligence – Functional safety and AI systems
- ISO/IEC 27005:2022, Information security, cybersecurity and privacy protection – Guidance on managing information security risks

So far, there are no international treaties or conventions that address the use of AI from a general perspective, possibly due to the rapid development of AI capabilities and the complexity of the issues involved. The European Union has recently given considerable attention to AI, both in support of further AI development and application, and to provide a legal framework to contribute to building trustworthy AI. The EU AI Act classifies AI based on its risk and obligates developers of high-risk AI systems (whether located in the EU or outside) to establish a risk management framework, exemplify best data governance practices, ensure human oversight, and provide appropriate accuracy, robustness, and cybersecurity measures.[25] The EU AI Act has a strong focus on protecting against unacceptable risk of AI systems, especially when AI applications are considered for use in social-economic service assessments or critical infrastructure.

25 European Union, "Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act)", 12 July 2024. Available at: https://eur-lex.europa.eu/eli/reg/2024/1689/oj/eng.

A further focus on AI-driven risks within the existing legal framework for nuclear security will be crucial to ensure the long-term security of nuclear facilities worldwide.

Discussion and Recommendations

AI provides both opportunities and risks. The potential to use AI applications to provide more informed assessments, e.g., of the prevailing threat, as well as in relation to the functioning of nuclear security measures, such as technical features for calculating the potential radiological consequences of an event, are positive contributions that may strengthen nuclear security. However, the risk that the same or similar technology could be used to provide incorrect or false information, impacting the overall assessment of the level of threat or the calculated consequences of an event must be considered.

The international legal framework has built much of its functions on the provision of information and collaboration among State Parties. The specific registry and reporting to other State Parties of nuclear or radiological events are defined in each convention or agreement. The value of interaction among State Parties is emphasised in the legal instruments. This interaction may be further enhanced using AI tools, without compromising the confidentiality of sensitive information.

The IAEA has started addressing AI in its work for nuclear safety standards and nuclear security guidance. However, to date, neither nuclear safety nor nuclear security standards and guidance have reached the stage of directly addressing AI questions.

The international standards organisations have started work to help ensure that AI products are safe, reliable, and of high quality. A “bottom-up” approach has been taken, i.e., identifying principles and measures to help civil society in using and trusting AI products.

The increased interest in nuclear energy, including the prospects of SMRs, will raise several questions related to safety, security, and non-proliferation/safeguards. AI may help in the analysis of addressing these questions, such as those related to type of fuel and management of potential accident scenarios and estimating the radiological and other consequences of the event, including measures to mitigate or recover from a nuclear security event, such as an act of sabotage and the subsequent dispersal of radioactivity.

The possibility for malicious actors to alter software or algorithms used in nuclear control systems and remain undetected deserves particular attention. Ways to improve detection of compromises to digital systems exist. Monitoring software systems to identify unwanted changes early and minimise the impact of potential consequences will require periodic analysis to enable early detection of attempts to compromise the software or algorithms.

In addition, progress in constructing advanced robots and drones must be monitored. The anticipated scenarios in which an unmanned item could pass through several nuclear facility checkpoints, some possibly protected as vital areas, to finally reach the intended target point will have to be analysed in detail to understand the feasibility and timeline of such a scenario and whether, if at all, it would be possible. In assessing these capabilities and its relevance to nuclear security, the principle of defence in depth, with layered protection and closed areas, together with the detection of an intrusion should be considered.

The question of revising nuclear security conventions and resolutions to strengthen protection against a potential AI threat has been raised as an option. The conventions and resolutions define the objectives, goals, and principles related to different areas of the infrastructure in which nuclear activities are implemented. However, they do not establish how this should be achieved. The principles, e.g., the Fundamental Principles outlined in the CPPNM Amendment, are general enough to conceptually include AI. This may support the view that AI and its impact on nuclear security could be handled within the present system. In addition, the revision of an existing convention is time-consuming, during which the rapid advancements in AI technology brings further doubt on whether the effort is sound and required.

Recommendations for Additional Work

At the Level of State Parties:

- Strengthen cooperation and interaction among State Parties to conventions, developed under the auspices of the IAEA, the UN, and the IMO.

- Identify common elements of the conventions and how reaching the goals could be facilitated through cooperation.

Addressing Specific AI Topics and Technologies:

- Identify specific AI applications that may help strengthen nuclear security analysis and functions; knowing the technology may simultaneously enhance the knowledge of AI in general and how it is used, and it may also enhance the awareness of potential misuse and how it should be dealt with.

- Explore possibilities to strengthen the authentication of information obtained through predictive and generative AI products, including credibility of source data and its use.

- Determine ways to ensure that software and algorithms used in nuclear control systems, for nuclear safety as well as nuclear security, stay uncompromised and are not maliciously altered without detection.

IAEA Nuclear Security Series and Guidance on AI Use:

- Review existing guidance published by the IAEA for possible revision to accommodate authentication and to ensure non-manipulated software or algorithms.
- Include in the review of existing IAEA NSS documents the potential of strengthening nuclear security by using artificial intelligence.
- Address AI management in peer reviews of nuclear security or safety.

International Standards Developed in the Civil Sector:

- Enhance awareness of AI-related standards developed by the civil sector standards organisations ISO and IEC, specifically the standards already developed on AI, its use, and management.
- Increase interaction with ISO and IEC to ensure that standards developed are mutually supporting and consistent.

Human Resource Development:

- Include AI awareness and knowledge of technology development and its applications in programmes for human resource development.

Advanced AI Robots and Drones:

- Monitor the development of advanced robots and drones for nuclear security considerations.

VCDNP

Vienna Center for Disarmament and Non-Proliferation

The VCDNP is an international non-governmental organisation that conducts research, facilitates dialogue, and builds capacity on nuclear non-proliferation and disarmament.

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