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NUCLEAR SECURITY DURING ARMED CONFLICT: LESSONS FROM UKRAINE

VITALY FEDCHENKO*

SUMMARY

● The attacks on nuclear installations in Ukraine by the Russian military in 2022 were unprecedented. Nuclear security aims at prevention, detection and response to malicious or unauthorized acts by non-state actors, not the armed forces of a state. However, an international armed conflict creates new circumstances in which a national nuclear security regime must operate.

In March 2022 the director general of the International Atomic Energy Agency (IAEA) highlighted 'seven indispensable pillars of nuclear safety and security' in extraordinary circumstances. There are three further areas in which the international nuclear security framework can be strengthened and prepared for extraordinary events, including armed conflict. First, there is a need to further clarify and plan the actions of competent authorities. Second, the IAEA may be able to assist member states in developing guidance for specific scenarios during extraordinary events. Third, there should be further integration of nuclear security with nuclear safety and emergency preparedness and response.

I. INTRODUCTION

The Russian military's invasion of Ukraine and attacks on nuclear installations there in 2022 presented extraordinary nuclear safety, security and safeguards challenges for the facilities' personnel, for the Ukrainian authorities and for the International Atomic Energy Agency (IAEA). Before 2022, no military attack had been directed at a large, operational nuclear power plant with a substantial inventory of irradiated nuclear fuel. These new—and extraordinary—challenges are very likely to have a significant impact on the international nuclear security regime. They thus require a thorough discussion of specific dimensions of the existing nuclear security framework related to extraordinary events—including war—and its relationship with other fields of international security. How can stakeholders in the nuclear security framework address new challenges brought about by the attacks on nuclear installations in Ukraine? What international legal instruments prohibiting such attacks are currently available, and how can they be reinforced? Which actors should have which responsibilities during nuclear security events that are initiated by the actions of armed forces? Should the nuclear security regime—which currently focuses on risks such as theft and terrorism—be adjusted to include elements to be activated in case of an attack by state actors (and if so, in what way)? Which actors should have responsibilities during nuclear security events involving armed forces, and what should those responsibilities be? How should the planning of nuclear security responses be structured in case of extraordinary events?

This paper addresses these questions, highlighting gaps in the current nuclear security regime and recommending how those gaps can be filled. It continues in section II with a review of the attacks on nuclear installations that took place in Ukraine in 2022 and places them against the background of earlier attacks on nuclear installations elsewhere. The paper reviews in section III existing and proposed legal protections against attacks on nuclear installations before discussing in section IV the 'seven indispensable pillars of nuclear safety and security' framework put forward by the IAEA director general as an emergency conceptual response to structure the assistance to Ukraine from the IAEA and its member states. Section V places the seven pillars concept against the background of the history of the nuclear security framework and shows why nuclear security is not meant, and has not been designed, to directly address attacks on nuclear instal-

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Table 1. Attacks on nuclear installations in Ukraine, February 2022–February 2023

Facility	Types of attack
Chornobyl NPP • Six reactor units (units 1–3 shut down; unit 4 partially destroyed in the 26 Apr. 1986 nuclear accident; units 5–6 never commissioned) • Two spent fuel interim storage facilities (ISF-1 and ISF-2) • Multiple radioactive waste-management and disposal facilities at the NPP site and in the wider Chornobyl Exclusion zone	Occupation, 24 Feb.–31 Mar. 2022
Khmelnytsky NPP • Two operational reactor units • Two reactor units under construction	Damage of power lines and other interruptions in electricity supply
Rivne NPP • Four operational reactor units	Damage of power lines and other interruptions in electricity supply
South Ukraine NPP • Three operational reactor units	Shelling Damage of power lines and other interruptions in electricity supply
Zaporizhzhia NPP • Six reactor units, operational as of 23 Feb. 2022, shut down by 10 Sep. 2022	Shelling Damage of power lines and other interruptions in electricity supply Occupation, 4 Mar. 2022– Annexation, 4 Oct. 2022–
Kharkiv Institute of Physics and Technology • Subcritical neutron source installation	Shelling
SSE 'Radon', Kharkiv branch • Radioactive waste management facility	Damage due to hostilities
SSE 'Radon', Kyiv branch • Radioactive waste management facility	Missile strike

NPP = Nuclear Power Plant; SSE = State Specialized Enterprise.

Source: International Atomic Energy Agency (IAEA), 'Nuclear safety, security and safeguards in Ukraine: 24 February–28 April 2022', Summary report by the Director General, 28 Apr. 2022; IAEA, 'Nuclear safety, security and safeguards in Ukraine: 28 April–5 September 2022', 2nd summary report by the Director General, 6 Sep. 2022; IAEA, Board of Governors, 'Nuclear safety, security and safeguards in Ukraine', Report by the Director General, GOV/2022/66, 10 Nov. 2022; Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA), 'Ukraine: Current status of nuclear power installations', 23 Jan. 2023; and IAEA, press releases, 2022.

during extraordinary events, including armed conflicts, shows that their preparedness for such events may be improved. Finally, section VII proposes a structured approach to the planning by nuclear security stakeholders of preparedness for and response to these events, and the paper closes in section VIII by offering conclusions and recommendations.

While the focus here is on the international nuclear security framework, a companion paper describes how attacks on nuclear installations in Ukraine have changed the national nuclear security regimes of states in the Black Sea region.[1]

[1] Fedchenko, V. et al., 'Nuclear Security in Ukraine and the Black Sea Region: New Threats, New Risks, New Consequences', SIPRI Research Policy Paper, Mar. 2022.

II. MILITARY ATTACKS ON NUCLEAR INSTALLATIONS IN UKRAINE AND BEFORE

At 6.41 a.m. CET on 24 February 2022 the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), serving in its capacity as national competent authority under the 1986 Convention on Early Notification of a Nuclear Accident, contacted the emergency response manager at the IAEA's Incident and Emergency Centre (IEC).[2] It informed the IEC that Russian troops were at the site of the Chornobyl Nuclear Power Plant (NPP) and that martial law had been imposed on the territory of Ukraine. In the evening of the same day the SNRIU reported that, as a result of a military attack, all facilities at Chornobyl had been taken over by the Russian military.[3]

This first attack was followed by many more. The IAEA has provided rigorous reporting documenting that, between February 2022 and February 2023, multiple nuclear facilities in Ukraine were subject to various kinds of hostile military action (see table 1).

Attacks on nuclear facilities and other installations in the nuclear fuel cycle have occurred previously, both during military conflicts and in peacetime.[4] Before 2022, nuclear installations were damaged by military strikes during war on at least five occasions. Between 1942 and 1944 the Allies made multiple attempts to destroy the Norsk Hydro heavy water-production facility in Telemark, Norway.[5] In 1950, as part of the strategic bombing campaign during the Korean War, the United States Air Force destroyed the chemical complex at Hungnam, North Korea, which was reportedly processing monazite for the Soviet nuclear programme.[6] On 30 September 1980, during the Iran–Iraq War, Iranian aircraft bombed the Osirak research reactor that was being built in Iraq, damaging ancillary buildings but missing the reactor itself.[7] Between 1984 and 1988 Iraq launched seven air attacks that eventually destroyed Iran's Bushehr NPP, which was in advanced stages of construction at the time.[8] During the 1990–91 Gulf War, the USA destroyed multiple Iraqi nuclear facilities.[9] In 2000 the US government compiled a list of four nuclear facilities in Iraq that both had nuclear or other radioactive materials on site and were damaged during the Gulf War: Tuwaitha nuclear research centre,

[2] Convention on Early Notification of a Nuclear Accident, opened for signature 26 Sep. 1986, entered into force 27 Oct. 1986, IAEA INFCIRC/335, 18 Nov. 1986.

[3] State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), 'Про ситуацію на Чорнобильській АЕС та стан безпеки інших ядерних установках' [On the situation at the Chornobyl NPP and the safety status of other nuclear facilities], 24 Feb. 2022; and IAEA, 'Nuclear safety, security and safeguards in Ukraine, 24 February–28 April 2022', Summary report by the Director General, 28 Apr. 2022, pp. 3, 8.

[4] On the definitions of 'nuclear facility', 'nuclear installation' and 'nuclear fuel cycle' see IAEA, *IAEA Nuclear Safety and Security Glossary: Terminology Used in Nuclear Safety, Nuclear Security, Radiation Protection and Emergency Preparedness and Response*, 2022 (interim) edn (IAEA: Vienna, 2022), pp. 135–37.

[5] Kreps, S. E. and Fuhrmann, M., 'Attacking the atom: Does bombing nuclear facilities affect proliferation?', *Journal of Strategic Studies*, vol 34, no. 2 (Apr. 2011), pp. 175–76.

[6] Futrell, R. F., *The United States Air Force in Korea, 1950–1953* (US Air Force, Office of Air Force History: Washington, DC, 1983), pp. 186, 190.

[7] US Director of Central Intelligence, 'National intelligence daily', 1 Oct. 1980, p. 1; and *The Economist*, 'The ghosts that hit Osirak', 18 Oct. 1980, p. 54.

[8] Spector, L. S., *Nuclear Ambitions: The Spread of Nuclear Weapons 1989–1990* (Westview Press: Boulder, CA, 1990), pp. 190, 208–209.

[9] Kreps and Fuhrmann (note 5), pp. 177–78.

Tarmiya uranium enrichment facility, Al Qaim superphosphate fertilizer plant and Mosul feed materials-production facility.[10]

Nuclear facilities have been attacked and destroyed in peacetime as well. In 1981 an Israeli air raid destroyed the Osirak reactor in Iraq.[11] In 1993 the USA used cruise missiles to destroy two Iraqi nuclear installations that had not been destroyed during the Gulf War.[12] In September 2007 a suspected undeclared nuclear facility located at al-Kibar, eastern Syria, was destroyed by an Israeli air strike.[13] Nuclear facilities have also been subject to cyberattacks—which are outside the scope of this paper—such as in the targeting by the Stuxnet computer virus of programmable logic controllers at the Fuel Enrichment Facility at Natanz in Iran in 2010.[14]

A number of differences set the events in Ukraine apart from the earlier attacks. First, no military attack was previously directed at a large, operational nuclear power plant, such as the Zaporizhzhia NPP, with a substantial inventory of irradiated nuclear fuel in reactor cores and in storage on site. This constitutes a fundamental difference from the previous attacks. The Zaporizhzhia NPP and Chornobyl NPP sites host facilities such as operational nuclear power plants and spent (irradiated) nuclear fuel storage, which means that the total amount of radioactivity present there is far larger than was present at any nuclear facility previously attacked.[15]

Second, none of the facilities targeted before 2022, except for Osirak, were placed under IAEA safeguards, the technical measures by which the IAEA verifies that nuclear materials and technology are used only for peaceful purposes. All Ukrainian nuclear facilities are under IAEA safeguards as part of the country's Comprehensive Safeguards Agreement with the IAEA and its Additional Protocol.[16]

Third, unlike in the case of Ukraine, most (but not all) known attacks on nuclear installations before 2022 were driven by the attacker's non-proliferation considerations. The Allies' concern about the heavy water produced in Norway was motivated by its potential use in reactors producing plutonium for weapons. The air attacks by the USA and Israel on Iraq in the 1980s and early 1990s aimed at destruction of the Iraqi nuclear weapon programme. The 1984–88 attacks by Iraq on Bushehr are an exception, because a nuclear power plant under construction was hardly a direct non-proliferation concern.

Fourth, attacks on nuclear installations before 2022 were specifically targeted at those facilities. In contrast, in 2022 the Russian military attacked a broad range of industrial facilities in Ukraine, including its power grid.

[10] US Defense Health Agency, 'Intelligence related to possible sources of radioactive contamination during the Persian Gulf War', July 2000.

[11] Feldman, S., 'The bombing of Osiraq—Revisited', *International Security*, vol. 7, no. 2 (fall 1982), p. 114.

[12] Kreps and Fuhrmann (note 5), p. 178.

[13] Kile, S. N., 'Nuclear arms control and non-proliferation', *SIPRI Yearbook 2010*, p. 393.

[14] Kile, S. N., 'Nuclear arms control and non-proliferation', *SIPRI Yearbook 2011*, p. 384.

[15] On 'high consequence facilities', such as NPPs, that contain enough nuclear and other radioactive material that, if dispersed, would lead to 'high radiological consequences' see IAEA, *Identification of Vital Areas at Nuclear Facilities: Technical Guidance*, IAEA Nuclear Security Series no. 16 (IAEA: Vienna, 2012), p. 1.

[16] Protocol Additional to the Agreement between Ukraine and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, entered into force 24 Jan. 2006, IAEA INFCIRC/550/Add.1, 18 June 2006.

Off-site power lines are necessary not only for the nuclear power plants to provide power to the Ukrainian electricity grid, but also to provide the plants with the power required for their safety functions. Even if a nuclear power plant were to be shut down, it would still need external power and water for an extended period of time to cool down nuclear fuel in the core. For example, immediately after shutdown, the nuclear fuel in a reactor of the size of those installed at Zaporizhzhia NPP would continue to produce about 200 megawatts (MW) of energy from residual decay heat.[17] The loss of off-site power or the plant's ultimate heat sink (e.g. water from a river or an ocean) could potentially lead to consequences similar to those of the Fukushima Daiichi nuclear accident in 2011.[18] The connection of Ukrainian NPPs to off-site power was interrupted multiple times in 2022 (see table 1), and on 23 November 2022 Russian missile strikes caused a decrease in the frequency in Ukraine's power system, which in turn caused the Rivne, South Ukraine and Khmelnytsky NPPs to automatically disconnect from the grid.

III. EXISTING AND PROPOSED LEGAL PROTECTIONS AGAINST ATTACKS ON NUCLEAR INSTALLATIONS

During an armed conflict, there is a high risk of damage to nuclear installations, especially if hostilities take place at or around a nuclear installation, with the consequent high risk of the release of radiation. Damage to the facility can be caused either directly or through an indirect breach of nuclear safety or security. This risk had been seen as significant enough to be recognized in international humanitarian law (IHL), which offers a few layers of legal protection.[19]

First, during an international (interstate) conflict, customary IHL and the 1977 Additional Protocol I to the 1949 Geneva Conventions dictate that nuclear power plants and other nuclear facilities associated with them, such as spent fuel storage facilities, are 'civilian objects' and as such should not have military operations directed at them.[20] In case there is doubt about whether a nuclear facility is dedicated to a civilian or military purpose, it should be presumed to be civilian.[21] Due to the risks of radiation release, the IHL obligation to do everything feasible to spare civilian objects is of particular importance.[22]

Second, in addition to protections afforded by IHL to all civilian nuclear installations, nuclear power plants enjoy protection against attack 'if such

[17] For more information see Schnieder, M. et al., *World Nuclear Industry: Status Report 2022* (Mycle Schneider Consulting: Paris, Oct. 2022), p. 245.

[18] IAEA, *The Fukushima Daiichi Accident*, Technical vol. 1/5, *Description and Context of the Accident* (IAEA: Vienna, Aug. 2015), pp. 2–32.

[19] Experts interviewed by author at Stockholm Security Conference, 10 Nov. 2022, and SIPRI Virtual Workshop on Nuclear Security, 20 Jan. 2023; and Zeith, A. and Giorgou, E., 'Dangerous forces: The protection of nuclear power plants in armed conflict', ICRC Humanitarian Law and Policy Blog, 18 Oct. 2022.

[20] Protocol I Additional to the 1949 Geneva Conventions, and Relating to the Protection of Victims of International Armed Conflicts, opened for signature 12 Dec. 1977, entered into force 7 Dec. 1978, Article 48; and Henkaerts, J.-M. and Doswald-Beck, L., *Customary International Humanitarian Law*, vol. 1, *Rules* (Cambridge University Press: Cambridge, 2005), p. 25.

[21] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 52.

[22] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 57(1); and Henkaerts and Doswald-Beck (note 20), p. 51.

attack may cause the release of dangerous forces and consequent severe losses among the civilian population'.[23] This holds even if a plant were to be found to be a military objective itself. During a non-international (intrastate) armed conflict in which the 1977 Additional Protocol II to the Geneva Conventions applies, this protection from attack applies even if a military objective is set up in the vicinity of a nuclear power plant.[24] In an international conflict, special protection afforded by Additional Protocol I for nuclear power plants or military objectives located in their vicinity may be lost if a nuclear power plant provides electrical power in regular, significant and direct support of military operations, and if an attack on the plant is the only feasible way to terminate such support.[25]

Additional Protocol I requires both sides to an international conflict to take measures to protect civilian forces.[26] One legal interpretation of the relevant articles by staff of the International Committee of the Red Cross (ICRC) suggests that the Geneva Conventions and customary law mandate the party to the conflict that controls the nuclear power plant to implement nuclear safety and nuclear security measures there 'as a matter of priority'.[27] According to this interpretation, those measures should include

> [(*a*)] ensuring the functional maintenance of critical components, including back-up generators; [(*b*)] ensuring operational staff can access the plant and/or critical components and are able to perform their tasks without undue restrictions, physical or psychological coercion, or any other form of unlawful treatment, and ensuring proper food and hygiene standards; [and (*c*)] if the safe and secure operation of the facility cannot be guaranteed, shutting down the power plant partly or fully.[28]

IHL treaty law does not consider the protections that it offers to nuclear power plants and, especially, other nuclear installations to be sufficient. States are urged in Additional Protocol I 'to conclude further agreements among themselves to provide additional protection for objects containing dangerous forces'.[29] Various legal formats of such protections have been discussed, and sometimes implemented by states, including the following cases.

Demilitarized zones and non-attack agreements

During hostilities or in peacetime, states may consider reaching agreement between themselves (bilateral or multilateral) to establish a demilitarized zone that parties to a conflict agree not to occupy, not to use for military purposes and not to attack. Additional Protocol I suggests a framework for such a zone, which is expected to be tailored by the parties to their needs.[30]

[23] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 56; Protocol II Additional to the 1949 Geneva Conventions, and Relating to the Protection of Victims of Non-International Armed Conflicts, opened for signature 12 Dec. 1977, entered into force 7 Dec. 1978, Article 15; and Henkaerts and Doswald-Beck (note 20), p. 139.

[24] Protocol II Additional to the 1949 Geneva Conventions (note 23), Article 15.

[25] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 56(2)(b)–(c).

[26] Protocol I Additional to the 1949 Geneva Conventions (note 20), articles 57(1), 58(c).

[27] Zeith and Giorgou (note 19).

[28] Zeith and Giorgou (note 19).

[29] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 56(6).

[30] Protocol I Additional to the 1949 Geneva Conventions (note 20), Article 60.

A unique example of a similar approach is the 1988 India–Pakistan Non-Attack Agreement.[31] Under this agreement both states not only agree not to attack in any way each other's nuclear installations of any kind, but also agree to exchange geographical coordinates of such installations once a year.

Along the same lines, in 1993 a US legal scholar proposed that the IAEA be vested with a 'right of initiative' to seek ad hoc agreements protecting specific safeguarded facilities during an armed conflict.[32] This proposal included the authorization of the IAEA director general to negotiate directly with the parties to a conflict.

The Pelindaba Treaty experience

The 1996 African Nuclear-Weapon-Free Zone Treaty (Treaty of Pelindaba) is unique among treaties establishing a nuclear weapon-free zone (NWFZ) because it prohibits attacks on nuclear installations: 'Each Party undertakes not to take, or assist, or encourage any action aimed at an armed attack by conventional or other means against nuclear installations in the African Nuclear-Weapon-Free Zone'.[33]

The Treaty of Pelindaba has a few features relevant to a general discussion of the legal arrangements prohibiting attacks on nuclear installations. The treaty negotiators discussed whether the protection of nuclear installations should be qualified. One option was to extend protections only in states parties to the treaty and only to facilities safeguarded by the IAEA, and thus 'certified' as being devoted to peaceful uses only. In the view of the US observers to the negotiations, these limitations would remove an opportunity for a state to exploit the treaty by placing radioactive material on a military objective and claiming protection.[34] In the end, this limitation was rejected by the negotiators, who concluded that the protection against attack should be extended to all nuclear facilities in all states in the NWFZ.[35]

Multilateral conventions

Multilateral conventions specifically prohibiting attacks on nuclear installations have been proposed multiple times in different forms, reflecting the realization that the protections of the Geneva Conventions described above are inadequate.

In 1979 the United States and the Soviet Union jointly submitted the text of a convention banning radiological weapons to the Committee on Disarmament in Geneva (renamed the Conference on Disarmament in 1984).

[31] India–Pakistan Agreement on the Prohibition of Attack against Nuclear Installations and Facilities, 31 Dec. 1988.

[32] Carnahan, B. M., 'Protecting nuclear facilities from military attack: Prospects after the Gulf War', *American Journal of International Law*, vol. 86, no. 3 (July 1992), pp. 533–34. On such an initiative for the Zaporizhzhia NPP in 2022 see Fedchenko, V., Maksymenko, I. and Sinovets, P., 'Attacks on nuclear installations in Ukraine and the IAEA response missions', *SIPRI Yearbook 2023: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, forthcoming 2023).

[33] African Nuclear-Weapon-Free Zone Treaty (Treaty of Pelindaba), opened for signature 11 Apr. 1996, entered into force 15 July 2009, Article 11.

[34] Adeniji, O., *The Treaty of Pelindaba*, UNIDIR/2002/16 (UN Institute for Disarmament Research: Geneva, 2002), p. 93.

[35] Adeniji (note 34), pp. 92–93.

Box 1. The seven indispensable pillars of nuclear safety and security

1. The physical integrity of the facilities—whether it is the reactors, fuel ponds or radioactive waste stores—must be maintained.
2. All safety and security systems and equipment must be fully functional at all times.
3. The operating staff must be able to fulfil their safety and security duties and have the capacity to make decisions free of undue pressure.
4. There must be secure off-site power supply from the grid for all nuclear sites.
5. There must be uninterrupted logistical supply chains and transportation to and from the sites.
6. There must be effective on-site and off-site radiation monitoring systems and emergency preparedness and response measures.
7. There must be reliable communications with the regulator and others.

Source: Grossi, R. M., IAEA Director General, Introductory statement to the IAEA Board of Governors, 2 Mar. 2022.

Sweden, supported by other neutral and non-aligned states, put forward a proposal to amend the draft by including a prohibition on attacking nuclear installations (i.e. reactors, reprocessing plants, and spent fuel and radioactive waste storage facilities above a certain size). The USA refused to accept the amendment, and Sweden and its supporters refused to drop it, so the convention was not negotiated.[36]

In 1992 a US scholar proposed a convention protecting safeguarded nuclear installations against any attack designed to eliminate them as potential sources of weapon-grade nuclear material.[37] In 2003 a former president of the Nuclear Law Association put forward an equally radical proposal to introduce 'the full-scale protection, in all circumstances, of all civilian nuclear installations'.[38]

IV. NUCLEAR SECURITY AND NUCLEAR SAFETY IN EXTRAORDINARY CIRCUMSTANCES: THE IAEA DIRECTOR GENERAL'S SEVEN PILLARS

Nuclear security concerns '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'.[39] The separate discipline of nuclear safety aims to achieve and maintain 'proper operating conditions, prevention of accidents and mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation risks'.[40] The distinction between nuclear safety and nuclear security can be summarized by saying that 'safety involves keeping sources of radiation away from people, while security involves keeping people away from sources of radiation'.[41] At a

[36] Carnahan (note 32), pp. 533–34.

[37] Carnahan (note 32), p. 540.

[38] Lamm, V., 'Protection of civilian nuclear installations in time of armed conflict', *Nuclear Law Bulletin*, no. 72 (Dec. 2003), p. 38.

[39] IAEA, *Objective and Essential Elements of a State's Nuclear Security Regime: Nuclear Security Fundamentals*, IAEA Nuclear Security Series no. 20 (IAEA: Vienna, 2013), p. 1.

[40] IAEA, *Glossary* (note 4), p. 139.

[41] Anthony, I., 'The role of the European Union in strengthening nuclear security', EU Non-proliferation and Disarmament Papers no. 13, EU Non-Proliferation Consortium, Nov. 2013, p. 2.

nuclear installation during both normal operation and extraordinary events, nuclear security provides a better opportunity for nuclear safety to achieve its goals by delaying (through detecting and responding) or deterring individuals with malicious intent.

This is particularly important for nuclear power plants. Among facilities in the nuclear fuel cycle, the largest inventories of highly radioactive materials are found in nuclear power reactors along with spent fuel storage facilities.[42] In the case of nuclear power plants, this radioactive material is enclosed in a relatively small but energy dense reactor core. High energy and radioactivity contained in a relatively small volume means that, should the containment and other barriers be breached, the potential for radioactivity release is significant. This is especially true if other nuclear safety systems are rendered inoperable, as happened, for example, during the Fukushima Daiichi accident.

On 2 March 2022, a few days after the first attack on a nuclear installation in Ukraine, the IAEA Board of Governors held a meeting to discuss the 'nuclear safety, security and safeguards implications of the conflict in Ukraine as a result of the Russian Federation's military operation that began on 24 February'.[43] In his introductory remarks the IAEA director general, Rafael Mariano Grossi, summarized the Russian military attacks on the Ukrainian nuclear infrastructure reported up to that date. He also noted that, despite the extraordinary circumstances, the nuclear facilities continued to operate 'normally' in a technical sense, but he emphasized that 'there is nothing normal about the circumstances under which the professionals at Ukraine's four nuclear power plants are managing to keep the reactors that produce half of Ukraine's electricity working'.[44]

In the same remarks, Grossi presented what later became known as his 'seven indispensable pillars of nuclear safety and security' framework (see box 1). The pillars are built upon the existing IAEA nuclear safety standards and nuclear security guidance documents and partly echo the above-mentioned ICRC recommendations.[45] In particular, Grossi stated that 'At the heart of nuclear safety are the three main safety functions: Containment, Control and Cooling', the maintenance of which requires his seven principles or 'pillars'.

The 'seven pillars' framework was widely endorsed by the international community.[46] Put forward less than a week after the first attack on a Ukrainian nuclear installation, Chornobyl NPP, and two days before the attack on the Zaporizhzhia NPP, this framework represents a rapidly deployed conceptual basis to underpin further action by both the IAEA and individual states. It should not be seen as a comprehensive list of principles, at least not without further elaboration by the IAEA. For instance, the safety function

[42] For a detailed discussion of the concept of the inventory of radioactive materials and its use in identification of vital areas of a nuclear facility see IAEA, Nuclear Security Series no. 16 (note 15).

[43] Grossi, R. M., IAEA Director General, Introductory statement to the IAEA Board of Governors, 2 Mar. 2022.

[44] Grossi (note 43).

[45] Zeith and Giorgou (note 19).

[46] World Nuclear Association, 'Statement on the IAEA framework for the safety and security of Ukraine's nuclear power plants', 10 Mar. 2022; and 'Joint statement on the High-level Meeting on the Safety and Security of Civil Nuclear Facilities in Armed Conflicts', US Department of State, 23 Sep. 2022.

of cooling mentioned by Grossi requires, among other things, availability of an ultimate heat sink such as a large body of water or the atmosphere. This can be used both as a source of cooling for turbine condensers during normal operation of the nuclear power plant and for heat discharge after the reactor shuts down.[47] Some experts have noted that the availability of a heat sink for cooling the reactors may merit its own pillar alongside the pillar requiring secure off-site power supply.[48]

From an operational perspective, the seven pillars have certainly been crucial for the IAEA and donor states when structuring their assistance and response to attacks on nuclear installations in Ukraine. From a strategic perspective, the seven pillars can be seen as a harbinger of an adjustment of the international nuclear security framework to face a new, previously largely unaddressed, set of scenarios: operation of national nuclear security regimes during attacks and disruption caused by states, rather than by non-state actors. To be clear: even during an international armed conflict, nuclear security itself is concerned with the malicious actions of individuals and non-state groups, not the actions of the armed forces of a state. However, in case of an international armed conflict or other such extraordinary circumstance, the nuclear security framework must continue to function, and this requires some adaptation.

To deal with this new set of scenarios the seven pillars explicitly address nuclear safety, nuclear security and emergency preparedness as part of the same conceptual package (see box 1). This unified approach is both logical and necessary, as well as being in line with existing IAEA policy. For example, for a number of years the IAEA has been developing the concept of the interface between nuclear safety and nuclear security, defined as 'Aspects of safety and security requirements and measures . . . that could mutually complement or counteract one another'.[49] Two top IAEA advisory bodies, the Advisory Committee on Nuclear Security (AdSec) and the International Nuclear Safety Group (INSAG), began to work on this concept jointly in 2017.[50] In 2018 the IAEA General Conference and Board of Governors formally requested the IAEA Secretariat to continue development of this concept, in cooperation with member states.[51]

Out of necessity, the seven pillars concept has been deployed rapidly. Unlike other nuclear security and nuclear safety guidance documents that are developed in a carefully scripted process with the participation and consent of the IAEA member states, the seven pillars were presented by the IAEA director general in his remarks to the Board of Governors. The concept is likely to require further elaboration by the IAEA with the participation of its member states. The next stages in this concept's development may require addressing questions such as the following: What is the status of the pillars

[47] IAEA, *Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants, Specific Safety Guide*, IAEA Safety Standards Series no. SSG-56 (IAEA: Vienna, 2020), pp. 32–35.

[48] Schnieder et al. (note 17), pp. 27–28; and Experts participating in SIPRI Virtual Workshop on Nuclear Security, 20 Jan. 2023.

[49] IAEA, *Management of the Interface between Nuclear Safety and Security for Research Reactors*, IAEA TECDOC Series no. 1801 (IAEA: Vienna, 2016), p. 2.

[50] Habib, A., 'Nuclear safety and security interface', 3rd International Regulators Conference on Nuclear Security, Marrakech, 1–3 Oct. 2019.

[51] IAEA, General Conference, 'Nuclear and radiation safety', Resolution GC(62)/RES/6, 20 Sep. 2018, para. 6.

concept in relation to existing IAEA guideline documents on safety, security and emergency response? What impact should it have on the laws and regulations of IAEA member states? How can it be ensured that elements of the nuclear security and nuclear safety frameworks that are not mentioned in the seven pillars concept are not deprioritized? Who is responsible for implementation of the seven pillars in cases where de jure and de facto control do not lie with the same authority (e.g. in case of occupation or annexation of a nuclear facility)?

V. NUCLEAR SECURITY BEFORE THE EVENTS OF 2022: THREE MILESTONES

Nuclear security as an international framework turned 50 in 2022. In June 1972 the IAEA prepared the first nuclear security guidance document, a booklet entitled 'Recommendations for the physical protection of nuclear material'. This was the first example of the IAEA's 'soft law'—that is, a principle that is widely accepted as an international norm, rather than a legal obligation—aimed at protection of nuclear material against theft or sabotage. Updated and reissued in 1975, it became the first milestone in the process of developing the international nuclear security framework and was actively used and revised multiple times in the coming decades.[52] The original document makes it clear that the 'basis for concern' is theft or sabotage by an individual or a 'technically competent group'.[53] In the international security context of the times, it was assumed that theft of nuclear materials was most likely to be a non-proliferation concern.[54]

The second milestone came with the decline and dissolution of the Soviet Union. As soon as the pervasive Soviet societal controls disappeared, the security of the materials of the Soviet nuclear complex became lax and even knowledge of the location of some materials became fragmented. The Soviet collapse led to sharp economic decline and wrenching societal change in the states of the former Soviet Union, which was compounded by the lack of public awareness of market values and the dangers of nuclear and other radioactive materials. As a result, people who had access to radioactive materials had a strong incentive to attempt to profit from them, and that led to a rise in the number of cases of theft and trafficking of nuclear and other radioactive materials in the late 1980s and, especially, the early 1990s. In addition, the dissolution of the Soviet Union resulted in a large volume of materials and radioactive sources becoming unaccounted for because the system originally developed for their physical protection, control and accounting either ceased to exist or malfunctioned. This occurred against the backdrop of the 1987 radioactive contamination accident at Goiânia, Goiás, Brazil, which served as a demonstration of the potential consequences of an event involving nuclear and other radioactive material out of regulatory

[52] IAEA, 'The physical protection of nuclear material', INFCIRC/225, Sep. 1975.

[53] IAEA, INFCIRC/225 (note 52), para. 4.1.1.

[54] On e.g. the 1965 NUMEC affair—an alleged theft of 100 kilograms of weapon-grade uranium for proliferation purposes—see Gilinsky, V. and Mattson, R. J., 'Did Israel steal bomb-grade uranium from the United States?', *Bulletin of the Atomic Scientists*, 17 Apr. 2014; and Gilinsky, V. and Mattson, R. J., 'Revisiting the NUMEC affair', *Bulletin of the Atomic Scientists*, vol. 66, no. 2 (2010).

Box 2. Elements of the international nuclear security framework

Multilateral conventions

The 1979 Convention on the Physical Protection of Nuclear Material and Nuclear Facilities (CPPNM) obligates its parties to protect nuclear material for peaceful purposes while in international transport.[a] A 2005 amendment strengthened the CPPNM by extending its scope to cover physical protection of nuclear facilities and nuclear material used for peaceful purposes in domestic use, storage and transport. It also criminalizes offences related to trafficking and sabotage of nuclear material or nuclear facilities and strengthens international nuclear security cooperation, such as assistance and information sharing in the event of sabotage. The amended treaty is known as the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities (A/CPPNM).[b]

Resolution 1540, adopted by the United Nations Security Council in April 2004, imposes binding obligations on all UN member states to establish domestic controls to prevent the proliferation of weapons of mass destruction (WMD) and their means of delivery. The obligations include establishing controls over nuclear materials that would prohibit non-state actors from obtaining nuclear weapons, in particular for terrorist purposes. To this end, the resolution mandates all states to establish physical protection, control and accounting measures for nuclear material and to combat its trafficking.[c]

The 2005 International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT) characterizes nuclear terrorism as a set of specific offences. It criminalizes unlawful and intentional possession and use of radioactive material or radioactive devices, as well as the unlawful use of or damage to nuclear facilities by non-state actors. It also provides an international legal framework for the investigation and prosecution of such offences.[d]

Global initiatives

The Global Partnership against the Spread of Weapons and Materials of Mass Destruction is a coordination mechanism for donors and recipients of international assistance that aims to prevent the proliferation of chemical, biological, radiological and nuclear (CBRN) weapons and related materials. The partnership comprises 30 states and the European Union (EU) and is led by the Group of Seven (G7) leading industrialized countries, which launched the partnership in 2002.[e]

The Global Initiative to Combat Nuclear Terrorism (GICNT), which was launched in 2006 and suspended in 2022, is a voluntary international partnership of countries that are committed to strengthening global capacity to prevent, detect and respond to nuclear terrorism. The GICNT conducts coordinated multilateral activities (e.g. exercises) to build the capacity of partner countries to combat nuclear terrorism.[f]

IAEA Nuclear Security Series guidance documents

The International Atomic Energy Agency (IAEA) Nuclear Security Series, launched in 2006, provides guidance to the IAEA member states on implementation of all aspects of nuclear security. The contents of each document in the series is agreed by a process of international consensus. While its recommendations are not mandatory, the Nuclear Security Series assists states in implementing or strengthening their nuclear security regimes.

[a] Convention on the Physical Protection of Nuclear Material, opened for signature 3 Mar. 1980, entered into force 8 Feb. 1987, IAEA INFCIRC/274, Nov. 1979.

[b] Convention on the Physical Protection of Nuclear Material and Nuclear Facilities, amendments to the 1979 convention adopted 8 July 2005, amended convention entered into force for its ratifying states 8 May 2016, IAEA INFCIRC/274/Rev.1/Mod.1, 9 May 2016.

[c] UN Security Council Resolution 1540, 28 Apr. 2004.

[d] International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 Sep. 2005, entered into force 7 July 2007.

[e] On the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction see its website, <https://www.gpwmd.com>.

[f] Joint Statement by US President George W. Bush and Russian President Vladimir Putin announcing the Global Initiative to Combat Nuclear Terrorism, 15 July 2006, *Public Papers of the Presidents of the United States: George W. Bush 2006*, book II (US Government Publishing Office: Washington, DC, 2010), pp. 1401–403.

[g] IAEA, 'Nuclear Security Series', [n.d.].

control (MORC).[55] Even though the accident involved only one radioactive source and no malicious intent, 249 people were contaminated with radioactive material, approximately 112 000 required medical monitoring, and an extensive clean-up operation required removal of blocks of buildings and topsoil.[56]

[55] On the definition of MORC, both reported and unreported, see IAEA, *Nuclear Security Recommendations on Nuclear and Other Radioactive Material Out of Regulatory Control*, IAEA Nuclear Security Series no. 15 (IAEA: Vienna, 2011), para 1.11.

[56] IAEA, *The Radiological Accident in Goiânia* (IAEA: Vienna, 1988).

The international nuclear security framework had to begin developing tools to deal with nuclear and other radioactive MORC, including to address the problem of orphan sources—sealed radioactive sources that are no longer under regulatory control.[57] As in the 1960s and 1970s, publications before 2001 discussed the need to keep nuclear materials under regulatory control as a non-proliferation measure. The threat of nuclear terrorism was mentioned but was not seen as the central issue.[58]

The terrorist attacks on the United States of 11 September 2001 were the third milestone in development of the international nuclear security framework. Although the attacks themselves did not involve nuclear or other radioactive material, they put the possibility of the mass destruction terrorism high on the political agenda. Combined with the lessons learned from events such as the Goiânia accident, the 2001 attacks provided a powerful political impetus to further conceptualize and implement a more comprehensive framework for nuclear security.

By 2022 the field of nuclear security was comprised of a robust, well-developed framework of international instruments. These included two international treaties, a number of global initiatives and a wide-ranging set of IAEA documents—the Nuclear Security Series—guiding implementation of specific facets of national nuclear security regimes in individual states (see box 2).

An international definition of nuclear security was published in 2005 in an IAEA General Conference document with a title that equated nuclear security with protection against nuclear terrorism.[59] The concept of nuclear terrorism was also included in the 2005 International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT). A comparison of the definition of 'nuclear security' in the IAEA document with the definition of 'nuclear terrorism' in ICSANT confirms that the former was now understood to mean defence against the latter.[60] Importantly, ICSANT makes it clear that an offence within the meaning of the convention can only be committed by a person, and Article 4(2) states that the actions of armed forces during an armed conflict or military forces of a state in the exercise of their official duties are not governed by the convention.[61] Also in 2005, an amendment to another foundational convention of the international nuclear security framework—the 1979 Convention on the Physical Protection of Nuclear Material (CPPNM)—was negotiated and agreed.[62] Article 2(4)(b) of the

[57] *Chicago Tribune*, 'Potatoes were guarded better', 8 Sep. 2004; and Shields, J. M. and Potter, W. C. (eds.), *Dismantling the Cold War* (MIT Press: Cambridge, MA, 1997).

[58] Allison, G. T. et al., *Avoiding Nuclear Anarchy* (MIT Press: Cambridge, MA, 1996), pp. 50–53. The notion of nuclear terrorism—and its connection to MORC—was not widely discussed before 2001, with one notable exception: McPhee, J., *The Curve of Binding Energy* (Farrar, Straus and Giroux: New York, 1974).

[59] IAEA, General Conference, 'Nuclear security—Measures to protect against nuclear terrorism: Progress report and nuclear security plan for 2006–2009', Report by the Director General, GC(49)/17, 23 Sep. 2005, para. 2.

[60] IAEA, GC(49)/17 (note 59), para. 2; and International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 Sep. 2005, entered into force 7 July 2007, Article 2.

[61] International Convention for the Suppression of Acts of Nuclear Terrorism (note 60), articles 2 and 4(2).

[62] Convention on the Physical Protection of Nuclear Material (CPPNM), opened for signature 3 Mar. 1980, entered into force 8 Feb. 1987, IAEA INFCIRC/274, Nov. 1979; and Convention on the Physical Protection of Nuclear Material and Nuclear Facilities (A/CPPNM), amendment to the

Box 3. Definitions related to nuclear security

Nuclear security regime

'A regime comprising:

- 'The legislative and regulatory framework and administrative systems and measures governing the nuclear security of nuclear material, other radioactive material, associated facilities, and associated activities,
- 'The institutions and organizations within the State responsible for ensuring the implementation of the legislative and regulatory framework and administrative systems of nuclear security,
- 'Nuclear security systems and nuclear security measures for the prevention of, detection of, and response to, nuclear security events.'[a]

Design basis threat (DBT)

'The attributes and characteristics of potential insider and/or external adversaries who might attempt unauthorized removal or sabotage, against which a physical protection system is designed and evaluated.'[b]

Operator

'Any person, organization, or government entity licensed or authorized to undertake the operation of an associated facility or to perform an associated activity.'[c]

Associated facility

'A facility (including associated buildings and equipment) in which nuclear material or other radioactive material is produced, processed, used, handled, stored or disposed of and for which an authorization is required.'[d]

Associated activity

'The possession, production, processing, use, handling, storage, disposal or transport of nuclear material or other radioactive material.'[e]

[a] International Atomic Energy Agency (IAEA), *IAEA Nuclear Safety and Security Glossary: Terminology Used in Nuclear Safety, Nuclear Security, Radiation Protection and Emergency Preparedness and Response*, 2022 (interim) edn (IAEA: Vienna, 2022), p. 141.

[b] International Atomic Energy Agency (IAEA), *National Nuclear Security Threat Assessment, Design Basis Threats and Representative Threat Statements: Implementing Guide*, IAEA Nuclear Security Series no. 10-G (Rev. 1) (IAEA: Vienna, 2021), p. 39.

[c] International Atomic Energy Agency (IAEA), *Objective and Essential Elements of a State's Nuclear Security Regime: Nuclear Security Fundamentals*, IAEA Nuclear Security Series no. 20 (IAEA: Vienna, 2013), p. 13.

[d] International Atomic Energy Agency (note a), p. 84.

[e] International Atomic Energy Agency (note a), p. 84.

amended convention—known as the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities (A/CPPNM)—contains exactly the same text as Article 4(2) of ICSANT.

To summarize, during the first half century of its development, regardless of the contemporary international security environment, the international nuclear security framework has always been intended and designed to address threats associated with non-state actors only. Indeed, the IAEA defines a 'threat' as 'A *person* or group of *persons* with motivation, intention and capability to commit a malicious act'.[63] Since 2005 this concept of threat has been codified in both international conventions underpinning the nuclear security framework—the ICSANT and the A/CPPNM—and implemented in essentially all guidance documents in the IAEA Nuclear Security Series.

CPPNM adopted 8 July 2005, amended convention entered into force for its ratifying states 8 May 2016, IAEA INFCIRC/274/Rev.1/Mod.1, 9 May 2016.

[63] IAEA, *Glossary* (note 4), p. 210 (emphasis added). On an equivalent but more formal and expanded definition see section VII of this paper.

VI. NATIONAL NUCLEAR SECURITY REGIMES AND ALLOCATION OF RESPONSIBILITIES TO ADDRESS THREATS

The central tenet of the international nuclear security framework is that the 'responsibility for nuclear security within a State rests entirely with the State'. Specifically, responsibility means that each state has to take steps to ensure 'the security of nuclear material, other radioactive material, associated facilities, and associated activities' under its jurisdiction.[64] This responsibility is fulfilled by creating and maintaining a national nuclear security regime. Simply put, a national nuclear security regime comprises legislation and regulations; institutions and organizations responsible for their implementation; and measures to prevent an unauthorized act or to detect and respond to such an act (see box 3 for a full definition).

It follows from this general definition that there are three types of national actor that have different kinds of responsibility in implementing a national nuclear security regime.[65] First is 'the state', that is, the top level of government, the legislature and the judiciary, which have a responsibility to manage national security, international relations and the armed forces, especially in critical situations such as armed conflict or other extraordinary events. The second type encompasses specific 'competent authorities', that is, governmental organizations designated by the state to carry out nuclear security functions. Examples of such authorities include, among others, regulatory bodies and agencies for law enforcement, customs and border control, intelligence, and security, as well as health agencies. The specific set-up of the first two types of actor—the state and the competent authorities—will be unique to each state, but there will always be a national actor performing each function, at least in principle. The third type of actor is any operator of a facility or activity involving nuclear or other radioactive materials, for example, a company owning and operating a nuclear power plant.

To define what are considered normal circumstances in terms of nuclear security, the IAEA and many national authorities use the term 'design basis threat' (DBT). This describes a potential 'threat' (i.e. adversary) against which nuclear security systems and measures, including physical protection of the facility, are designed to be effective (see box 3). If a threat is within the parameters of the DBT—for example, an individual caught trying to steal nuclear fuel pellets from their place of work—the situation, although serious, can still be considered normal in the sense that it was planned for.

The state will manage the competent authorities as they conduct the national nuclear security threat assessment and develop the DBT. Under normal circumstances the operator of a facility is responsible for the nuclear security of the facility and of the nuclear or other radioactive material in it (or in transport), as well as for nuclear safety and radiation protection. The operator must put in place nuclear security systems and measures to protect against the range of attack scenarios foreseen in the DBT. The design and set-up of those systems and measures must meet specific requirements put

[64] IAEA, Nuclear Security Series no. 20 (note 39), p. 1.

[65] IAEA, *National Nuclear Security Threat Assessment, Design Basis Threats and Representative Threat Statements: Implementing Guide*, IAEA Nuclear Security Series no. 10-G (Rev. 1) (IAEA: Vienna, 2021), pp. 12–14.

Table 2. Allocation of nuclear security responsibilities in normal and extraordinary circumstances

This summary is based on the IAEA Nuclear Security Series guidance documents and on recommendations by experts interviewed by SIPRI.

Actor	Normal circumstances	Extraordinary circumstances
State	Manage competent authorities in development of national nuclear security threat assessment and DBT	Deal with nuclear security threats beyond the DBT
Competent authorities	Participate in development of nuclear security threat assessment Provide facility operators with requirements for nuclear security systems and measures	. . (not defined in the document IAEA Nuclear Security Series no. 10-G (Rev. 1))
Operator	Meet the requirements for nuclear security systems and measures against threats defined in the DBT	Meet the requirements for nuclear security systems and measures against threats defined in the DBT Assist the state in dealing with nuclear security threats beyond the DBT Assist the state in mitigating the consequences of extraordinary events

DBT = design basis threat; IAEA = International Atomic Energy Agency.

Sources: IAEA, *National Nuclear Security Threat Assessment, Design Basis Threats and Representative Threat Statements: Implementing Guide*, IAEA Nuclear Security Series no. 10-G (Rev. 1) (IAEA: Vienna, 2021), pp. 12–14, 26; Stockholm Security Conference, 10 Nov. 2022; and SIPRI Virtual Workshop on Nuclear Security, 20 Jan. 2023.

forward by the regulatory authorities as a result of their understanding of the DBT.[66]

The distribution of nuclear security responsibilities will naturally change during extraordinary circumstances (see table 2).[67] During extraordinary events the state has the responsibility for dealing with nuclear security threats that are not envisioned in the DBT—and so are not the responsibility of the operator. However, the operator's responsibilities during the extraordinary events do not cease. First, it is expected to assist the state in dealing with the threats beyond the DBT, as well as in mitigating the consequences afterwards. Second, top nuclear security experts interviewed by SIPRI agree that—to the extent possible—the operator is responsible for meeting threats within the parameters of the DBT even during extraordinary events, including armed conflict.[68]

There is little public information on the extent to which preparations for extraordinary circumstances have been made in specific countries. However, interviewed experts agreed that the topic of actions and responsibilities of various national (and international) nuclear security actors during extraordinary events—whether national, regional or global, including armed conflicts—is clearly underdeveloped. As explained by one top expert from a country with leading nuclear security capabilities, 'while the operator has primary responsibility for defending against threats within the DBT, and the state for threats beyond the DBT, in most countries (including my own) the state really hasn't made serious preparations for actually responding to beyond-DBT threats'.[69] While states must do more to address this problem, IAEA guidance should also be developed further to complement national

[66] IAEA, Nuclear Security Series no. 10-G (note 65), pp. 12–14.
[67] IAEA, Nuclear Security Series no. 10-G (note 65), p. 26.
[68] Experts interviewed (note 19).
[69] Expert participating in SIPRI Virtual Workshop on Nuclear Security, 20 Jan. 2023.

efforts. The experience of the concepts of protection of nuclear installations against potential external events (e.g. volcanic activity, external fire and explosions, radiological hazards from other installations and, in particular, aircraft impacts) at the stages of facility design, construction and operation is likely to prove useful.[70]

VII. PLANNING NUCLEAR SECURITY RESPONSE TO EXTRAORDINARY EVENTS

There is a need to structure the approach to planning the actions of nuclear security stakeholders in extraordinary events or in response to nuclear security threats beyond the DBT. This structure should have four main elements.

First, the planning approach needs to recognize that extraordinary events with a serious impact on nuclear security may not have nuclear security threats associated with them. The IAEA definition of a nuclear security threat is

> A person or group of persons with motivation, intention and capability to commit criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities or other acts determined by the State to have an adverse impact on nuclear security.[71]

In essence, 'a threat is a postulated adversary against whom security measures are designed'.[72] Extraordinary events such as the Covid-19 pandemic or a large-scale natural disaster (e.g. an earthquake followed by a tsunami) have specific nuclear security implications but involve no adversaries beyond those already defined in the DBT. Post-pandemic literature has begun to consider the lessons learned for the operation of nuclear security regimes during extraordinary events that, while changing the circumstances in which the regimes operate, do not change the set of threats or adversaries that the regimes should address.[73] Similarly, in an armed conflict, an attack that is not targeted at a nuclear facility may still have an impact on nuclear security there. For example, damage to the national energy infrastructure may leave surveillance cameras and other nuclear security systems at the nuclear facility without power.

Second, although this study was motivated by the necessity of understanding the effects of a military invasion and war on national nuclear security regimes, it must be recognized that nuclear security threats beyond the DBT exist in other scenarios as well. In addition to a war between states, examples of such scenarios include state collapse (i.e. failed states) and large-scale civil unrest. Incidents involving threats beyond the DBT should be categorized by their scale, because the scale will determine the actors involved and, therefore, the distribution of responsibilities.[74] One option is to follow a pattern in IHL and categorize incidents that affect nuclear

[70] IAEA, *Design of Nuclear Installations Against External Events Excluding Earthquakes: Specific Safety Guide*, IAEA Safety Standards Series no. SSG-68 (IAEA: Vienna, 2021), pp. 38–82.

[71] IAEA, Nuclear Security Series no. 20 (note 39), p. 13.

[72] IAEA, *Glossary* (note 4), p. 14.

[73] E.g. Chapman, G. et al., *Nuclear Security in Times of Crisis*, Centre for Science and Security Studies (CSSS) Occasional Paper Series (King's College London: London, May 2021).

[74] Former top IAEA nuclear security official, Email communication with author, 27 Jan. 2023.

security as international or national. International incidents would include, for example, international armed conflicts—that is, hostilities between two or more states. National incidents that affect nuclear security might be non-international armed conflicts—that is, hostilities between a state and non-state armed groups or only between non-state armed groups—such as in scenarios of riots or state collapse.[75] The last category will partially overlap with threats within the DBT, which is likely to include armed groups up to a certain size.

Third, the main concerns of national nuclear security regimes during armed conflicts should be to prevent radioactive release from nuclear installations and to prevent nuclear and other radioactive materials leaving regulatory control. National planning for armed conflicts (international and national) will have to consider scenarios involving intentional and inadvertent incidents. For example, an attacker may want to intentionally cause a radioactive release from a nuclear power plant, while a war may cause general disruptions in supply chains or availability of electricity with inadvertent consequences at a nuclear facility. At the planning stage, the state will have to decide if nuclear facility operators should have any responsibility for reducing vulnerability at least to inadvertent events during military activities (e.g. stray shells and extended interruptions of off-site power). The IAEA guidance on this issue is brief but does suggest that an operator may be assigned such a role.[76]

Fourth, a robust planning framework and capability for national response have to be established for the three scenarios identified above: (*a*) extraordinary events with an impact on nuclear security but without nuclear security threats beyond the DBT (e.g. a pandemic or a natural disaster), (*b*) international armed conflicts and (*c*) non-international (intrastate) armed conflicts. Such planning may exist to some degree in some countries for some scenarios, but this is uncommon. The nuclear security planning for each of the three scenarios should ideally have the following four features.

1. National nuclear security planning should be comprehensive—it should cover all relevant functions and stakeholders and as many relevant contingencies as feasible.

2. National nuclear security planning should be formalized and its components should be distributed across governmental authorities. Previous studies demonstrate that, even in states with more developed nuclear security regimes, not all authorities are aware of their responsibilities.[77]

3. The plan in question should be adopted at the appropriate level with appropriate legal force, and authorities' responsibilities

[75] Bartels, R., 'The classification of armed conflicts by international criminal courts and tribunals', *International Criminal Law Review*, vol. 20, no. 4 (Aug. 2020).

[76] See table 2 above; and IAEA, Nuclear Security Series no. 10-G (note 65), p. 26.

[77] Fedchenko V. and Anthony, I., *Nuclear Security in the Black Sea Region: Contested Spaces, National Capacities and Multinational Potential*, SIPRI Policy Paper no. 49 (SIPRI: Stockholm, Dec. 2018).

should be binding (i.e. authorities should have no choice but to respond as prescribed in the plan).

4. The plan should be regularly tested in dedicated exercises. The findings from these exercises should then be used to update the plan.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Although attacks on nuclear installations by state actors have happened many times before, they are dwarfed by the shelling, missile strikes, occupation and annexation of nuclear facilities, including large operational nuclear power plants, that happened in Ukraine in 2022. For five decades between 1972 and 2022 the global development of the nuclear security regime occurred in parallel with relatively rare cases of attacks on nuclear installations, without a significant mutual influence. Nuclear security has always aimed at prevention, detection and response to malicious or unauthorized acts by non-state actors. This aim is codified in both foundational nuclear security conventions—the ICSANT and the A/CPPNM—and permeates all the guidance documents of the IAEA Nuclear Security Series. Changing this state of affairs would mean renegotiating the whole international nuclear security regime.

There is, therefore, no good argument for an expansion of the definition of nuclear security to cover actions of states and their armed forces. The interviewed legal experts were adamant that the legal frameworks for combatting nuclear terrorism (i.e. nuclear security) and international humanitarian law 'should not be mixed': they serve different purposes and have different foundations. Mixing these legal frameworks will require reopening for negotiations the international conventions that underpin them—the Geneva Conventions, ICSANT and the A/CPPNM—and rewriting a large part of the IAEA nuclear security guidance documents. Equally, there is no compelling reason to recommend steps such as the preparation of physical protection systems to withstand an assault on a nuclear facility by regular armed forces. Such preparation is simply not feasible in cases where an adversary has access to contemporary weapons such as advanced missiles, as the potential cost would be prohibitive. Experts and officials that were interviewed for this study agreed that the responsibility to combat nuclear security threats beyond the DBT, such as foreign military units, should remain with the armed forces of a state.

However, there are three areas where the nuclear security framework can be strengthened and prepared for extraordinary events, including armed conflict.

First, there is a need to further clarify and plan the actions of competent authorities, in particular nuclear facility operators, during such events. Each national nuclear security regime should plan how the operator of a nuclear facility should perform the following three functions during extraordinary events: (*a*) meet the requirements for nuclear security systems and measures against threats defined in the DBT; (*b*) assist the state in dealing with threats beyond the DBT; and (*c*) assist the state in mitigating the consequences of the extraordinary events.

Second, the IAEA may be able to assist member states in developing guidance for specific scenarios of the application of nuclear security during extraordinary events. States may use mechanisms such as consultancy meetings to work with the IAEA to identify specific scenarios or topics of a particular interest to them, such as preparedness and operation of nuclear security systems and measures against threats defined in the DBT during extraordinary events.

Third, for many years the nuclear security regime has been developing interconnections with other frameworks relevant to extraordinary events: nuclear safety and emergency preparedness and response (and even, to a smaller extent, international humanitarian law). As discussed above, the IAEA has recognized the interdependence of nuclear safety and nuclear security and has begun to develop documents addressing both, and there has been similar work on the interface between nuclear security and emergency preparedness. There should be further integration between these three disciplines. The events in Ukraine are likely to provide an impetus for this.

ABBREVIATIONS

A/CPPNM	Convention on the Physical Protection of Nuclear Material and Nuclear Facilities
DBT	Design basis threat
IAEA	International Atomic Energy Agency
ICRC	International Committee of the Red Cross
ICSANT	International Convention for the Suppression of Acts of Nuclear Terrorism
IEC	Incident and Emergency Centre (IAEA)
IHL	International humanitarian law
MORC	Material out of regulatory control
NPP	Nuclear Power Plant
NWFZ	Nuclear weapon-free zone
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine

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ABOUT THE AUTHOR

Vitaly Fedchenko (Russia) is a Senior Researcher with SIPRI's Weapons of Mass Destruction Programme, where he is responsible for nuclear security issues and the political, technological and educational dimensions of nuclear arms control and non-proliferation. He is the author or co-author of multiple publications on nuclear forensics, nuclear security and nuclear non-proliferation, including *The New Nuclear Forensics* (Oxford University Press, 2015).

STOCKHOLM INTERNATIONAL PEACE RESEARCH INSTITUTE
Signalistgatan 9
SE-169 72 Solna, Sweden
Telephone: +46 8 655 97 00
Email: sipri@sipri.org
Internet: www.sipri.org