TRACKING THE FALLOUT: A TIMELINE OF RUSSIAN ASSAULTS ON UKRAINIAN NUCLEAR POWER PLANTS AND TESTING OF THE IAEA'S SEVEN PILLARS (2022-2025)

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ABSTRACT

The protracted Russia-Ukraine conflict poses a significant threat to the security and safety of the nuclear power facilities in that region. Since the start of the conflict, Russian forces have taken control of Ukraine's nuclear power plants, including Zaporizhzhia and Chernobyl. This situational paper provides an overview of the various events that transpired around the Ukrainian nuclear power plants during this armed conflict. It covers a timeline from 2022 to early 2025, documenting attacks, drone incursions, cyber threats, and power disruptions. It examines how these events tested the IAEA's Seven Pillars of nuclear safety: physical infrastructure; safety and security systems; staff conditions; off-site power; logistics; radiation monitoring; and communications. All of these faced continued stress revealing vulnerabilities in operational and regulatory frameworks. The IAEA's monitoring and technical interventions provided critical oversight and mitigated potential disasters, but legal and practical limitations remain. The findings highlight the urgent need for reinforced safeguards, resilient infrastructure, and strengthened international legal mechanisms to protect nuclear facilities in contemporary armed conflicts.

Keywords: Nuclear safety, IAEA Seven Pillars, Russia, Ukraine, Zaporizhzhia Nuclear Power Plant (ZNPP)

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1. INTRODUCTION

The Russo-Ukraine War, which began in 2014, escalated dramatically on 24 February 2022 when Russia launched a full-scale invasion.[1] The troubling aspect of the conflict was Russia's repeated targeting of Ukraine's nuclear energy sector which generates about half of its electricity from fifteen nuclear reactors spread across four power plants, the majority of which are VVER designs, which is a pressurised water reactor, from the Soviet era.[2] Among these, Russian military took control of the largest nuclear facility in Europe, the six-unit Zaporizhzhia Nuclear Power Plant (ZNPP),[3] as well as the Chernobyl site which had been closed since the 1986,[4] reflecting larger threats involved. The use of nuclear sites as military targets represent a significant departure from established wartime norms that seek to safeguard civilian infrastructure.

To address nuclear safety and security concerns amid the on-going Russia-Ukraine conflict, IAEA Director General Rafael Mariano Grossi unveiled the Seven Indispensable Pillars in March 2022.[5] The objective was to outline the requirements for maintaining nuclear sites safely during siege, maintaining the physical integrity of structures, and keeping safety and security systems functional.

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[1] Fahad Abbas, *THE U.S. ROLE IN THE RUSSIA-UKRAINE CONFLICT: FROM SUPPORT TO SECURITY GUARANTEES* (ISSI, 2025), https://issi.org.pk/wp-content/uploads/2025/08/IB_Fahad_Aug_15_2025.pdf.

[2] Rostyslav Khotin, 'US Boots on The Ground In Ukraine? Trump's Nuclear Power Proposal Turns Heads', Ukraine, *Radio Free Europe/Radio Liberty*, 2025, https://www.rferl.org/a/ukraine-nuclear-plants-russia-americans/33355266.html.

[3] Alejandro Zurita, 'The Zaporizhzhia Nuclear Power Plant Taken as Military Target: Legal and Technical Global Challenges', 2024, https://www.cidob.org/en/publications/zaporizhzhia-nuclear-power-plant-taken-military-target-legal-and-technical-global.

[4] Susan D'Agostino, 'Russian Forces Now Control Chernobyl, Inviting Speculation and Uncertainty', *Bulletin of the Atomic Scientists*, 25 February 2022, https://thebulletin.org/2022/02/russian-forces-now-control-chernobyl-inviting-speculation-and-uncertainty/.

[5] Nuclear Energy Agency (NEA), 'NEA Supports the IAEA 7 Pillars of Nuclear Security and Safety', 2022, https://www.oecd-nea.org/jcms/pl_66360/nea-supports-the-iaea-7-pillars-of-nuclear-security-and-safety.

This study provides the timeline of how each of the Russian attacks on Ukrainian nuclear sites from 2022 to early 2025 put the IAEA's pillars to the test. It examines incidents like the March 2022 Russian takeover of Zaporizhzhia NPP, the April 2022 occupation and evacuation of Chernobyl, and subsequent threats at Khmelnytskyi, Rivne, and other plants. The study also examines how the IAEA and plant operators responded, as well as which pillars were tested. Furthermore, it highlights vulnerabilities of the safety regime and provides recommendations for safeguarding nuclear infrastructure in future conflicts by analysing each incident in light of IAEA seven pillars.

2. THE IAEA'S FRAMEWORK FOR NUCLEAR SAFETY: SEVEN PILLARS

During the Russia-Ukraine war, when operational nuclear power plants became active conflict zones for the first time in history, the IAEA Director General Rafael Grossi, in early 2022, announced seven indispensable pillars for maintaining nuclear facilities' safety and security under extreme pressure. The IAEA's Seven Pillars of Nuclear Safety and Security provided a useful framework from maintaining reactor integrity and power supply to guaranteeing staff autonomy and efficient communication with regulators. The IAEA's Seven Indispensable Pillars of nuclear safety during conflict are given below.[6]

2.1. Physical integrity: Hostilities must not damage reactor buildings, cooling ponds, or waste storage facilities. Any impact on a pond or containment could result in a leak. Even nearby shelling poses a risk during a war because debris or fire could breach the structure.

[6] Vienna Center for Disarmament and Non-Proliferation, 'Nuclear Sites at Risk and the IAEA's Seven Pillars - Vienna Center for Disarmament and Non-Proliferation', 2023, https://vcdnp.org/nuclear-sites-at-risk-and-the-iaeas-seven-pillars/.

2.2. Safety and security systems: All technical devices, such as radiation detectors, coolant pumps, emergency generators, and alarms, must continue to function. Cooling or containment may be rendered inoperable by damage to transformers, valves, or controls. Although there are backup plans in case of emergencies, war damage necessitates their use right away.

2.3. Staff conditions: Operators and technicians of plants must operate in a safe environment free from coercion. Under attack, employees may be arrested, threatened, or made to stay after their shifts. Staff members' capacity to maintain safety is undermined by stress and exhaustion.

2.4. Off-site power supply: Pumps and instruments used by nuclear units are powered by the civilian grid. Transmission lines are frequently the target of wartime attacks, which results in blackouts. Reactors must use diesel generators in the event of a grid power outage. Maintaining a steady grid connection, or having enough fuel and generators, is essential for on-going cooling.

2.5. Logistics and supply chains: The plant needs constant delivery of fuel, spare parts, and other essential supplies. Roads, railroads, and ports may be blocked by armed conflict. Maintenance and emergency response are negatively impacted if diesel fuel, replacement filters, or batteries are not delivered. Maintaining open supply routes is a requirement of Pillar 5.

2.6. Radiation monitoring: Continuous radiation level monitoring and leak detection are required from both on-site and off-site sensors. Operator visibility is lost if war damages these sensors or disrupts their data links. When built-in systems malfunction, it is critical to restore monitoring (through IAEA mobile units).

2.7. Communication: Contact between the plant, its operator, the national regulator, and international organisations (such as the IAEA) must be continuous. War has the power to cut off radio, internet, and phone connections. Maintaining those channels makes it possible to coordinate critical safety decisions, such as reactor shutdowns or public alerts.[7]

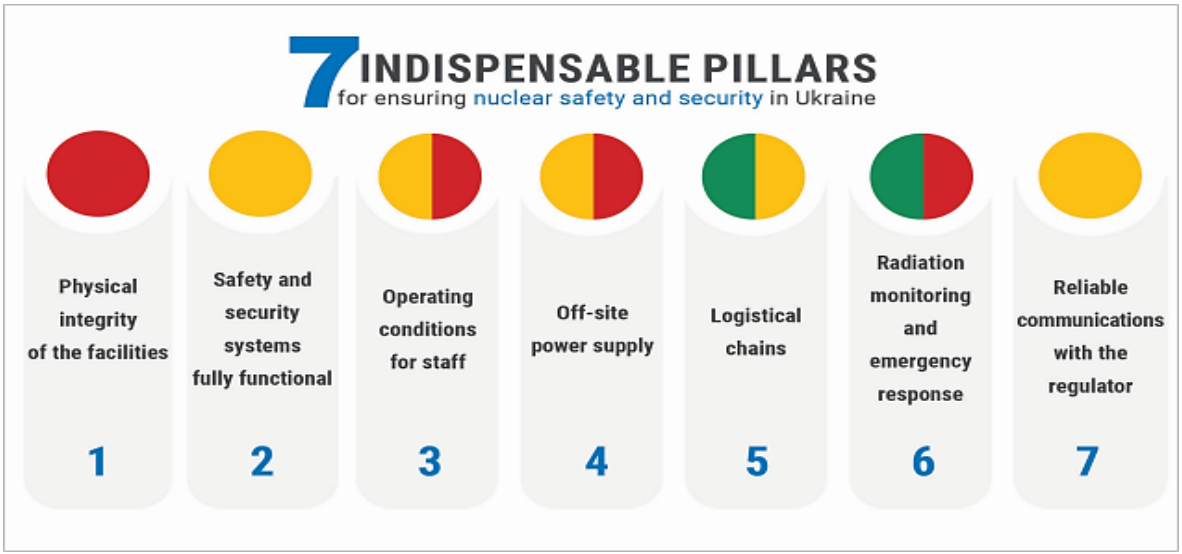

Figure 1. IAEA Seven Pillars

The IAEA's seven essential pillars for guaranteeing nuclear safety and security during Ukraine conflict have been partially or completely undermined by the events that have transpired since the beginning of the conflict for practically all nuclear facilities and numerous activities involving radioactive sources in Ukraine.[8]

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[7] 'IAEA Director General Grossi's Initiative to Travel to Ukraine', Text, IAEA, 4 March 2022, https://www.iaea.org/newscenter/pressreleases/iaea-director-general-grossis-initiative-to-travel-to-ukraine.

[8] IAEA, *NUCLEAR SAFETY, SECURITY AND SAFEGUARDS IN UKRAINE* (2023), https://www.iaea.org/sites/default/files/documents/nuclear-safety-security-and-safeguards-in-ukraine-feb-2023.pdf.

3. TIMELINE OF RUSSIAN MILITARY ACTIVITY AND ITS IMPACT ON UKRAINIAN NUCLEAR SITES (2022-2025)

3.1. Zaporizhzhia Nuclear Power Plant (ZNPP) (2022)

The ZNPP was taken by Russian troops on 4 March 2022. Shells landed in the plant as the fighting moved closer to Enerhodar. About 300 meters from Unit 1, a shell hit the training centre, starting a fire that was quickly put out. Offices, communications building, and nearby labs were also damaged. Crucially, there were no breaches in any of the spent fuel ponds or reactor containment buildings. The armed forces arrested Ukrainian operators, but they kept operating the reactors, which were immediately put into cold shutdown. The Ukrainian regulator and the IAEA expressed alarm, with the IAEA calling the situation as more urgent than ever.[9]

When the ZNPP was occupied in 2022, Russian tanks, trucks, and infantry carriers were stationed there. Explosives were kept in turbine halls, creating a serious fire risk. About 500 troops and 50 vehicles were on the ground by August of that year. The ZNPP was used by Russian forces as a shield as well as a military base. Mines were placed all around it, particularly close to the Kakhovka reservoir and cooling pond.[10] These were purportedly defensive actions taken to discourage Ukrainian attack or sabotage. As a result of these actions, the biggest nuclear facility in Europe became a military base and a possible nuclear hazard heightening the safety concerns.

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[9] United Nations, 'Situation at Zaporizhzhia Nuclear Power Plant Very Alarming, International Atomic Energy Agency Director General Tells Security Council | Meetings Coverage and Press Releases', 2022, https://press.un.org/en/2022/sc14996.doc.htm?utm.

[10] United Nations, *Prevention of Armed Conflict - The Situation in the Temporarily Occupied Territories of Ukraine* (2022).

Drone attacks, artillery fire, and repeated Ukrainian attempts to retake the ZNPP have made it a focal point of the conflict, and both sides continue to accuse one another of direct and indirect attacks.[11] Blackouts have repeatedly occurred throughout Ukraine as a result of military operations close to the nuclear plant, disrupting both industry and civilian life. These events highlight the plant's precarious position, where the threat of a nuclear emergency continuously threatens its function as a vital energy supplier. The blurring of military goals with civilian nuclear infrastructure highlights Ukraine's energy security's vulnerability and significant ramifications for international nuclear safety standards.

3.2. Chernobyl (2022)

After the invasion of 24 February 2022, Russian forces occupied Chernobyl site for a month. Military vehicles frequently moved through the Red Forest during the occupation,[12] which is the most radioactively contaminated part of the zone. Satellite imagery suggested that Russian soldiers were exposed to unhealthy levels of radioactivity. However, the IAEA did not verify these reports.[13]

Russian forces withdrew from the site on 30-31March 2022, following which the Ukrainian officials claimed that they discovered the site severely damaged. While the protective structures surrounding the old reactor and waste remained intact, thousands

[11] Reuters, 'Russia, Ukraine Accuse Each Other of Plotting Imminent Attack on Nuclear Plant', 2023, https://www.reuters.com/world/europe/russia-ukraine-accuse-each-other-plotting-imminent-attack-nuclear-station-2023-07-04/.

[12] *Russians Drove through 'Red Forest', Chernobyl Workers Report Incident from Last February*, directed by WION, 2022, 02:13, https://www.youtube.com/watch?v=slqQXLJGtdY.

[13] Geoff Brumfiel, 'Satellite Photo Shows Russian Troops Were Stationed in Chernobyl's Radioactive Zone', Ukraine Invasion — Explained, *NPR*, 7 April 2022, https://www.npr.org/2022/04/07/1091396292/satellite-photo-shows-russian-troops-were-stationed-in-chernobyls-radioactive-zo.

of computers, vehicles, and monitoring equipment had been either destroyed or stolen.[14]

3.3. ZNPP Precarious Position (2023)

Due to damage to its vital 750 kV and 330 kV transmission lines, the ZNPP experienced multiple outages in 2023 and occasionally had to rely on diesel generators. The plant was forced to rely on groundwater wells for cooling after the Nova Kakhovka dam was destroyed, further complicating the situation. The long-term safety concerns of ZNPP grew as a result of reduced staff, fewer spare parts, and restricted access. Although apprehensions about potential military use remained, the IAEA maintained a permanent presence on the site throughout the year, with DG Rafael Grossi visiting multiple times and outlining fundamental principles to prevent disaster. By October 2023, only two reactors remained in hot shutdown to provide heating, while the majority had been placed in cold shutdown, placing the facility at the centre of a global nuclear safety crisis.[15]

3.4. Drones near Khmelnytskyi and Rivne (2024)

Russian strikes accelerated through drone attacks throughout 2024. A Shahed drone was seen flying near the Khmelnytskyi Nuclear Power Plant (NPP) in September 2024. Another drone was seen flying at a low-height close to the Rivne NPP perimeter on the evening of September 24-25, 2024[16] and another flew over Khmelnytskyi's turbine hall in late October. In each instance, the plants automatically scrambled or shut

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[14] *Ukraine War: Chernobyl Scarred by Russian Troops' Damage and Looting*, 3 June 2022, https://www.bbc.com/news/world-europe-61685643.

[15] 'Ukraine: Russia-Ukraine War and Nuclear Energy - World Nuclear Association', 2025, https://world-nuclear.org/information-library/country-profiles/countries-t-z/ukraine-russia-war-and-nuclear-energy.

[16] Artur Kryzhnyi, 'Russian UAV Nearly Hits Rivne Nuclear Power Plant', Ukrainska Pravda, 2024, https://www.pravda.com.ua/eng/news/2024/09/26/7476887/.

down reactors as a precaution and initiated full emergency procedures right away. Monitoring stations waited for any release while air defence units tried to shoot down the drones. Radiation levels were normal and no reactor was damaged. These incidents demonstrated that spotting drones flying close to the NPPs was enough to set off highest-level safety alarms. The IAEA reaffirmed that putting reactors in danger is against international law and condemned Russia's disregard for previous safety warnings.[17]

3.5. Cyber and communication threats (2025)

In 2025, Russia launched a sustained campaign of kinetic, cyber, and electronic warfare threats against Ukraine's nuclear facilities. Cyberattacks interfered with plant monitoring and control systems, and a Russian drone hit the Chernobyl New Safe Confinement in February, causing structural damage but no radiation leak.[18] When Ukrainian drones targeted a training facility in July, strikes on the ZNPP once again caused blackouts. At the same time, there were reports of on-going Russian cyber intrusions, malware deployment, and data theft.[19] Since the start of invasion, communications between the ZNPP and the national regulator were frequently interrupted, highlighting the crucial role of reliable links for command-and-control and nuclear security. The IAEA also emphasised on this deteriorating situation and said it is extremely concerning particularly in the midst of an armed conflict that could jeopardise

[17] IAEA, *Nuclear Safety, Security and Safeguards in Ukraine - Report by the Director General* (2024), https://www.iaea.org/sites/default/files/documents/gov2024-63.pdf.
[18] Nuclear Newswire, 'IAEA: Chernobyl Drone Strike Latest Threat to Nuclear Safety in Ukraine', 2025, https://www.ans.org/news/2025-02-18/article-6767/iaea-chernobyl-drone-strike-latest-threat-to-nuclear-safety-in-ukraine/.
[19] CSIS, *Significant Cyber Incidents Since 2006*, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-06/250610_Significant_Cyber_Incidents.pdf?VersionId=IAAkHurCCF.s7dd26zpWQUXbumz3JXsq.

the safety and security of the plant.[20] Table 1 demonstrates the risks faced by Ukraine's nuclear sites during the timeline of 2022 and 2025.

Year	Site	Key Events	Impact
2022	Zaporizhzhia (ZNPP)	Russian forces seized the plant; shelling caused fires; explosives stored on-site; staff detained.	Used as a military base; severe safety concerns; repeated blackouts; triggered global alarm over nuclear risks.
2022	Chernobyl	Occupied for a month; troops moved through the Red Forest; site looted and damaged.	Possible troop radiation exposure; monitoring systems destroyed; reactor shelter remained intact.
2023	Zaporizhzhia (ZNPP)	Power lines damaged; outages and cooling issues; IAEA maintained a continuous presence.	Escalated nuclear safety risks; two reactors in hot shutdown; international concern intensified.
2024	Khmelnytskyi & Rivne	Armed drones flew near plants; emergency shutdowns triggered; no physical damage reported.	Heightened threat perception; IAEA condemned drone activity; psychological alarm despite no damage.
2025	ZNPP & Chernobyl	Cyberattacks and drone strikes; damage to Chernobyl cover; communications disrupted.	Oversight severely weakened; convergence of physical and cyber threats; IAEA labelled situation alarming.

Table 1. Risks to Ukraine's Nuclear Sites, 2022–2025.[21]

[20] 'Russian Forces Interfering at Ukraine Nuclear Plant: IAEA', Al Jazeera, 2022, https://www.aljazeera.com/news/2022/3/6/staff-at-ukraines-nuclear-plant-now-under-russian-order-iaea.
[21] Author's Compilation.

4. ASSESSMENT: HOW EACH IAEA PILLAR WAS TESTED?

4.1. Physical Integrity of Facilities (P-1)

This pillar requires the preservation of waste storage facilities, spent fuel ponds, and reactor buildings. The ZNPP in particular has had its physical integrity repeatedly threatened by Russian military actions in Ukraine, which have damaged reactor buildings, cooling systems, and vital electrical infrastructure. Critical safety systems have been interfered with by these attacks, necessitating the use of emergency backup generators.[22]

The site has become a military objective in the war. It remains surrounded by artillery, with multiple reports of repeated artillery fire near the site. Furthermore, drone attacks have targeted Ukrainian NPPs including ZNPP. The IAEA has confirmed the tangible effects on these facilities, such as the damage to communication and monitoring systems and reactor buildings, emphasising the threat to operational structural integrity and a risk of nuclear accident.[23] Ukrainian NPPs' reactor containments have largely resisted attacks, nevertheless, every direct threat has shown that Pillar 1 remained vulnerable and under constant strain.

4.2. Functionality of Safety and Security Systems (P-2)

All security apparatus (fences, cameras) and safety systems (cooling pumps, valves, backup generators, alarms) must continue to function as per Piller 2. Contrary to this stipulation, all these have experienced severe strain as well as damages. Russian

[22] IAEA, 'Update 290 – IAEA Director General Statement on Situation in Ukraine', Text, IAEA, 8 May 2025, https://www.iaea.org/newscenter/pressreleases/update-290-iaea-director-general-statement-on-situation-in-ukraine.
[23] 'Attacks on Ukrainian Nuclear Facilities Must Cease Immediately: UN Atomic Watchdog | UN News', 8 April 2024, https://news.un.org/en/story/2024/04/1148346.

forces have disrupted off-site power which is necessary for cooling systems, has attacked close to nuclear facilities, and captured/occupied strategic locations, including the Zaporizhzhia and Chornobyl NPPs, endangering safe operations. For instance, during the August 2022 Zaporizhzhia grid outage, reactor cores were kept cool by diesel generators and emergency pumps. The region's nuclear infrastructure has been constantly in danger as a result of these actions, which violates international nuclear safety standards and presents significant threats to regional and international security.[24]

4.3. Staff Conditions (P-3)

This pillar calls for operators to work independently, however, they have been subjected to severe pressures in Ukrainian NPPs. Ukrainian employees have operated reactors while under armed occupation for over three years now. They frequently lived in makeshift camps under constant military surveillance and were isolated for weeks. According to Ukraine, ZNPP employees endured mistreatment, continual military supervision, threats, and forced labour. Stress and fatigue raised the possibility of errors, putting Pillar 3 to the test, but staff members' extraordinary human endurance allowed them to continue operations in the face of on-going threats.[25]

4.4. Off-site Power Supply Stability (P-4)

Reactor cooling at nuclear sites depends on backup water and continuous grid electricity, but both were frequently interrupted by the war in this region. ZNPP has been undergoing several complete blackouts since the start of the war. In 2022, shelling on

[24] Department of Energy (DOE) and National Nuclear Security Administration (NNSA), *Russia's Disregard for Nuclear Safety and Security in Ukraine* (2023), https://www.energy.gov/sites/default/files/2023-03/NA-80%20Ukraine%20Factsheet.pdf.
[25] Hanna Arhirova, 'Ukraine Nuclear Workers Accuse Russians of Abuse: Terrible Things Happen There - National | Globalnews.Ca', Global News, 2022, https://globalnews.ca/news/9179853/ukraine-nuclear-workers-russians-abuse/.

external 750 kV, Dniprovska, power transmission line resulted in several complete blackouts at Zaporizhzhia. After the Kakhovka dam was destroyed in 2023, ZNPP had to rely on wells for cooling, which are sufficient only when reactors are shut down but cannot provide enough water if the reactors are restarted.[26]

In each case, all cooling was provided for days by emergency diesel generators. Ukraine had large diesel tanks ready (enough for each reactor to cool for about a week), and more generators were delivered as the demand for both houses and businesses increased.[27] However, these incidents drove Pillar 4 to the verge of failure because overheating could have resulted from a single mistake (disabled generator, empty fuel tanks). Other facilities also lost grid power; for example, in late 2022 and early 2023, automatic shutdowns at Rivne and South Ukraine were triggered by nationwide power outages.[28]

4.5. Reliable logistics and supply chains (P-5)

Ukrainian export routes, particularly in the Black Sea, have been disrupted by the Russia-Ukraine war, leading to the creation of alternate routes known as the “Solidarity Lanes” raising the costs and causing logistical delays.[29] This has had repercussions for delivering equipment, fuel, and spare parts. Encircled by front lines, Zaporizhzhia occasionally had to wait several days for basic technical supplies like dosimeters and

[26] Francois Murphy, ‘No Sign of Preparations to Restart Zaporizhzhia, IAEA Official Says’, Energy, *Reuters*, 29 May 2025, https://www.reuters.com/business/energy/no-sign-preparations-restart-zaporizhzhia-iaea-official-says-2025-05-29/.
[27] International Energy Charter, *Ukrainian Energy Sector Evaluation and Damage Assessment - VI* (2023), https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_01_24_UA_sectoral_evaluation_and_damage_assessment_Version_VI.pdf.
[28] ‘Ukraine: Russia-Ukraine War and Nuclear Energy - World Nuclear Association’.
[29] Stanislav Zinchenko, ‘How the Russia-Ukraine War Has Impacted on Logistics Routes and Supply Chains’, *GMK*, 2024, https://gmk.center/en/posts/how-the-russia-ukraine-war-has-impacted-on-logistics-routes-and-supply-chains/.

filtration parts, as well as food and medical assistance. Moreover, months of research were halted at Chernobyl when retreating Russians destroyed piled materials.[30] Staff made improvised repairs to keep vital supplies flowing putting severe pressure on the provisions of pillar five.

4.6. Radiation monitoring systems (P-6)

Constant monitoring, both on and off site, was crucial but often compromised. Due to conflict-related damage, a number of radiation monitoring stations within a 30-kilometer radius of the ZNPP have been out of commission since early 2022 for varied lengths of time. Currently, four stations, which is more than a quarter of the fourteen that existed prior to the conflict, are not operational.[31] In response to the conflict, the IAEA has built remote monitoring systems at each NPP unit, allowing them to provide information to the IAEA. The architecture of surveillance systems allows for the transfer of signals from video cameras deployed at NPPs to the IAEA headquarters in Vienna via the worldwide network.[32] Although the IAEA used mobile units to collect and transmit radiation readings, Pillar 6 was violated because of prolonged blackouts and damage to facilities.

4.7. Robust communication with regulator and operator (P-7)

Communication between plant operators, regulators, and international observers is critical to nuclear safety. Communication at the ZNPP was severely disrupted after

[30] the London Free Press, 'Mothersill: War in Ukraine Halts Research at Chernobyl | London Free Press', 2022, https://lfpress.com/opinion/columnists/mothersill-war-in-ukraine-halts-research-at-chernobyl.
[31] IAEA, 'Update 235 – IAEA Director General Statement on Situation in Ukraine', Text, IAEA, 27 June 2024, https://www.iaea.org/newscenter/pressreleases/update-235-iaea-director-general-statement-on-situation-in-ukraine-0.
[32] IAEA, *On Compliance of Ukraine with Obligations under the Convention on Nuclear Safety* (2022), https://www.iaea.org/sites/default/files/24/01/9th_national_report_cns_ukraine.pdf.

Russian forces took over the facility. The initial severance of direct links to Ukraine's regulator, SNRIU, and competing claims of authority caused confusion. The IAEA facilitated communication via secure channels, such as satellite phones and radios. Later on, contact with the regulator was restored, and the IAEA delivered equipment and resumed the safeguards monitoring system.[33] These efforts highlighted the strain on Pillar 7 which deals with communication and coordination during wartime conditions.

These events reflect that all the pillars designated by the IAEA for safe operations of NPPS have remained under significant stress throughout the duration of the conflict. Containment was nearly breached by shelling and sabotage (Pillar 1); safety systems were only kept operational by constant backups (Pillar 2); staff worked under distressed conditions (Pillar 3); multiple blackouts were caused by grid losses (Pillar 4); supplies were routed around battle zones (Pillar 5); IAEA teams had to improvise monitoring (Pillar 6); and plant-regulator communication depended on emergency networks (Pillar 7). All this has resulted in the need for greater international scrutiny over NPPs in war zones owing to the potentially devastating implications of breach in any one domain.

5. ROLE OF THE IAEA: LIMITATIONS AND ACHIEVEMENTS

The IAEA has been playing a significant role throughout the while of this conflict. It established a monitoring presence at Ukraine's plants and sent high-level missions on multiple occasions. On top of having a core team of multinational employees at ZNPP and other stations, the Agency has maintained 24-hour observance at strategic locations throughout the war. Moreover, DG Grossi has publicly shamed both sides for

[33] Antony Frogatt and Dr Patricia Lewis, 'Attacks on Ukraine Nuclear Plant – What's at Stake? | Chatham House – International Affairs Think Tank', 2022, https://www.chathamhouse.org/2022/08/attacks-ukraine-nuclear-plant-whats-stake.

putting NPPs in danger. At a press conference, he warned of the reactors' vulnerability, emphasising the potential for catastrophic consequences in the event of an attack.[34]

The IAEA received strong international support, including from the Security Council, for its Seven Indispensable Pillars of Nuclear Safety and Security.[35] However, despite this backing, its ability to operate on the ground has been limited by challenges to its neutrality and restricted access to nuclear facilities. While maintaining presence and communication on site, IAEA teams had to deal with political roadblock, delays, and physical threats from drone alerts and nearby shelling. The agency, in spite of these obstacles, has made significant progress. It has provided a central role in the supervision of technical support and assistance in the conflict area. Furthermore, its monitoring reports have assisted in preventing false information regarding purported releases. Therefore, even though the IAEA was unable to stop interference or exert control over either party's actions, its efforts have been essential in maintaining oversight and on-ground reporting.

6. FUTURE OF NUCLEAR SAFETY IN ARMED CONFLICTS

Nuclear risks have increased dramatically as a result of the on-going conflict between Russia and Ukraine, especially at locations like the ZNPP, where military occupation has increased the potential for attacks and disruptions. Tensions have increased as a result of Russia's repeated threats of using nuclear weapons and Ukraine's corresponding targeted military attacks. In the absence of immediate international attention and preventive measures, territorial disputes and conflicting

[34] Darya Dolzikova, 'Kursk Nuclear Power Plant: The Newest Target for Russian Disinformation', 2024, https://www.rusi.orghttps://www.rusi.org.
[35] United States Mission to the United Nations, 'Remarks at a UN Security Council Briefing on Ukraine', *United States Mission to the United Nations*, 15 April 2024, https://usun.usmission.gov/remarks-at-a-un-security-council-briefing-on-ukraine-7/.

ceasefire conditions complicate negotiations and could escalate into a larger nuclear crisis, posing serious threats to regional and global security and undermining long-standing international norms.[36]

There has been a history of inter-state wars but other than Operation Babylon in which Iraqi nuclear plant was struck, there is hardly an example of wars leading to a threat to NPPs. Their security and safety are of utmost importance, and an attack on them could result in catastrophic consequences. Russia has not directly attacked a NPP, it rather attacked nearby areas as an intimidation tactic. While the Russian President Vladimir Putin has not made any public comments about the alleged Chernobyl plant attack. the Ukrainian government presents it as a deliberate attack on nuclear facilities. Russian stance is that the news and updates about the Chernobyl attack and human catastrophes are propaganda. Looking at the whole situation, it can be assumed that Russia was aiming to send strong political signalling to the West through these moves.

In times of armed conflict, nuclear facilities are only partially protected by international law. Although there are no outright bans, the 1949 Geneva Conventions' Additional Protocols I and II provide some guidance. There are only some protections offered by broader nuclear and environmental law principles. Practical measures like bilateral agreements or demilitarised zones can be beneficial in this regard but they depend on the consent and political will of both sides. So far, there has been no direct attack on a nuclear plant. However, incidents in the vicinity of ZNPP and other NPPs

[36] Shumaila Saeed, 'Russia - Ukraine War: A Threat to Nuclear Security', *Modern Diplomacy*, 30 November 2024, https://moderndiplomacy.eu/2024/11/30/russia-ukraine-war-a-threat-to-nuclear-security/.

highlight the grave dangers and repercussions of these legal loopholes.[37] Weak legal frameworks limit the IAEA's ability to protect nuclear sites, underscoring the necessity of a treaty that forbids attacks on such sites. The attacks on Ukraine's nuclear sites demonstrates how contemporary warfare can turn nuclear plants into strategic liabilities. To safeguard IAEA's Pillars (1-7) in any future armed conflict, there is a need to combine diplomacy and law, ensuring both compliance and practical protection on the ground.

7. CONCLUSION

With every facet of the IAEA's Seven Pillars of nuclear safety are being put to the test. The conflict in Ukraine has exposed the vulnerability of nuclear facilities like Zaporizhzhia to military, cyber, and logistical pressures. The limitations of operational safeguards have been highlighted by frequent power outages, supply interruptions, and interference with monitoring and communication systems. The IAEA's technical supervision has served as a stabilising factor throughout to prevent any major catastrophe. However, it also exposed weaknesses in international legal protections for nuclear sites in armed conflict. The crucial lesson is that safeguarding nuclear infrastructure in contemporary warfare requires both immediate technical solutions (such as backups, drills, and hardened systems) and more robust regulations, such as explicit bans on attacking or militarising reactors. This also calls for a global commitment to nuclear security, strong technical safeguards, fortified legal frameworks, and proactive strategies to address changing threats for maintaining the safety and security of nuclear facilities. The IAEA's pillars will only remain strong if the international community takes action to support them.

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[37] Gábor Kecskés, *The Protection of Nuclear Installations in Time of Armed Conflict – Old Rules, New Challenges*, Hungarian Journal of Legal Studies, 18 September 2024, https://doi.org/10.1556/2052.2024.00511.

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