

GROWING IMPACTS OF ARMED CONFLICTS OVER NUCLEAR SAFETY



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The impacts of armed conflicts on nuclear facilities are not entirely new in history since in last decades diverse nuclear installations became targets in various conflicts. During the Iraq-Iran war (1980-88), the under-construction Iraqi Osirak research reactor, of French Osiris design and located at the Tuwaitha nuclear research centre, was bombed in 1980 by Iranian airstrikes and destroyed completely in 1981 by Israeli airstrikes. Later Iraq bombed several times between 1984-1987 the two under-construction units of the Iranian Bushehr nuclear power plant (NPP) of German Siemens/KWU design. During the Gulf war (1990-91), the referred Iraqi Tuwaitha nuclear centre was again bombed in 1991 by the U.S., while also in the same year the Israeli Dimona nuclear centre was attacked by Iraqi missiles. However, today's conflicts in Ukraine and in the Middle East are drawing nuclear installations into wars in ways not previously seen.



Figure 1. Painting "To the war" - Konstantin Savitski (1844-1905).

UKRAINE

The Ukrainian Zaporizhzhia NPP was seized by Russia in March 2022 and has remained a contested military objective ever since. This situation represented the first military occupation of an operating commercial NPP, a scenario for which the international community was largely unprepared.

The vulnerability of the Zaporizhzhia NPP is primarily associated with the erosion of the defence-in-depth concept. Although the plant's six reactor units have basically remained in cold shutdown since September 2022, the reduction in safety and security margins is mainly attributed to two major challenges. The first one is the persistent instability of the Ukrainian electrical grid, which has been repeatedly damaged by military actions, resulting in an unreliable external power supply to the plant. At present, only one 330 kV backup power line remains available out of the ten high-voltage lines (four 750 kV lines and six 330 kV backup lines) connecting the site. Consequently, the Zaporizhzhia NPP has already experienced at least twenty-one complete losses of off-site power supply, requiring the emergency diesel generators to operate as the ultimate safety backup.

Such emergency conditions appear to be unprecedented during the 37 years of operation preceding the conflict. The second major challenge is associated with the destruction of the Kakhovka dam in June 2023, which emptied the Dnieper water reservoir. The plant's cooling capability currently relies on the structural integrity and stability of the cooling pond, as well as on the eleven wells drilled at the plant site that



Figure 2. Open sprinklers as link for the crucial cooling chain at Zaporizhzhia NPP.

together with the steadiness of the unprotected sprinkler systems should ensure the cooling chain of nuclear fuels.

Furthermore, the plant has been subjected to repeated shelling, explosions, drone strikes and sabotages. Notable incidents include the shelling of the fresh nuclear fuel and solid radioactive waste storage facility in August 2022, a fire that rendered one of the two cooling towers inoperable in August 2024, and a drone strike that perforated the turbine hall of unit 6 in May 2026. The nuclear safety and security at the Zaporizhzhia NPP remain highly precarious and are considered unsustainable over the medium term [1-2].

In addition, other Ukrainian nuclear installations have been affected by the war. In March 2022, the NSC KIPT Nuclear Research Centre in Kharkiv and the KINR Nuclear Research Centre in Kyiv were struck. During the occupation of the Chernobyl site in early 2022, nuclear safety was compromised through the loss of the external power supply. Subsequently, in February 2025, a drone strike penetrated the roof of the New Safe Confinement over the accidented unit 4 of the Chernobyl NPP, damaging the outer cladding, insulation and crane systems.

The role of inspectors from the International Atomic Energy Agency (IAEA) in Zaporizhzhia and in the other three operating Ukrainian NPPs plus Chernobyl is contributing to maintain minimum levels of nuclear safety and security and to provide independent account of events and developments helping to establish information amid competing narratives. In relation to the referred instable power supply to the Zaporizhzhia NPP with each time more frequent losses of the off-site power supply, IAEA negotiated six local ceasefire arrangements to enable the reparation of different electrical substations located far away from the plant and the reconnection of off-site power lines.

MIDDLE EAST

After the disappointing collapse of the international nuclear deal with Iran¹ in recent years [3-4], specific talks took place between U.S. and Iran. However, those negotiations ended abruptly in June 2025 with the outbreak of the so-called Twelve-Day war, started with two waves of bombing raids conducted by Israel and the U.S. on Iranian facilities, in particular on the uranium enrichment plants in Natanz

¹ The Joint Comprehensive Plan Of Action (JCPOA) was signed in July 2015 between Iran and the nuclear powers of the UN Security Council (China, France, Russia, United Kingdom and United States) plus the European Union and Germany. The United States withdrew from the JCPOA in May 2018 and reinstated sanctions against Iran.



Figure 3. Drone strike on the New Safety Containment of unit 4 of Chernobyl NPP.

and Fordow, the Isfahan nuclear centre and the under-construction Khondab IR-40 heavy water reactor. The full extent of damages remains uncertain, as Iran did not grant the IAEA access to the targeted facilities.

Following the resumption of U.S. and Israeli attacks against Iran in February 2026, the conflict expanded across several countries in the Middle East. In this context, numerous components of the nuclear fuel cycle and industrial facilities in Iran were struck, including yellowcake production, enrichment facilities, and other industrial sites using small radioactive sources. Moreover, an area in the vicinity of the Israeli Dimona nuclear centre and the site of the Iranian Bushehr NPP, a German-Russian² designed plant, were also attacked. The four attacks on the latter during March and April 2026 prompted Russia, which is constructing units 2 and 3 at the Bushehr site, to warn of unpredictable consequences. When the U.S. President threatened to destroy key Iranian infrastructure, including power plants, stating that the largest facility would be targeted first, that statement was interpreted as referring to the Bushehr NPP. In addition, the Emirati Barakah NPP, comprising four reactor units, was also targeted by drone strikes on last 17 May. The attacks damaged electrical generators and forced the use of emergency diesel generators to supply power to unit 3.

To date, IAEA inspectors have been able to access only the Bushehr NPP and the Tehran Research Reactor (TRR), as well as the Barakah NPP. No increases in radiation levels above natural background were reported and normal operations continued, but the involvement of civilian nuclear installations in the ongoing Middle East conflict has reached unprecedented qualitative and quantitative dimensions.

Following the latest escalation, a new attack on the Bushehr NPP occurred just on last 8 July, reportedly affecting the perimeter of the site. Current attacks on NPP sites are still interpreted primarily as warning or intimidation tactics. However, considering the extensive military capabilities of the enemies involved, the potential consequences for the safety and security of nuclear facilities could be considerably more severe.

A PARADIGM SHIFT

Both, the historical attacks and the more recent ones perpetrated in the wars of Ukraine and Middle East, affected

² The construction of two Siemens/KWU reactors in Bushehr started in 1975, but after the Islamic revolution in 1979 the contracts were cancelled at construction levels of respectively 85% and 50%. During the Iraq-Iran war, both units were damaged by Iraqi air strikes, and the construction of only one reactor was later completed by Rosatom over the infrastructures of Siemens/KWU, with a unique VVER-1000 reactor. The plant, connected to the grid in 2012, is also linked to desalination processes.

NPPs, research reactors, radioactive facilities, as well as enrichment, reprocessing and nuclear fuel fabrication plants. The implication in armed conflicts of multiple components of the civil nuclear fuel cycle is becoming somehow normalised and is a real challenge for nuclear safety and security.

In extreme cases, such events could have severe implications for the safety and security of nuclear installations, potentially leading to fuel meltdown scenarios involving spent fuel pools and storage facilities, reactor cores, or radioactive waste facilities. The consequences of such severe accidents would depend on the scope of the damage and on the specific radioactive source terms associated with the affected installations. Further to the population density³ as relevant factor in scenarios with radioactive releases, another consideration is that many components of the nuclear fuel cycle -potentially targets during armed conflicts- lack the containment structures designed to limit radioactive releases, as is typically the case for NPPs. Nevertheless, the safety and security of NPPs can also be compromised through precise attacks against specific systems or components located outside the reactor containments.

Beyond conventional military approaches, new strategies of warfare have emerged in current hybrid and asymmetric conflicts. For example, cyberattacks are becoming increasingly sophisticated, while advances in drone technologies enable more accurate targeting, also to specific components of nuclear installations. These emerging technologies could also potentially be exploited by terrorist groups to target civilian nuclear facilities.

Within the framework of those wars, various political statements referring to the potential limited use of tactical nuclear weapons have also emerged. Such references are reaching mainstream public discourse in a way that would have been unthinkable until very recently. This development could further increase the involvement of nuclear facilities in armed conflicts, as such actions might be perceived by some actors as representing a lesser-evil scenario compared with the use of nuclear weapons themselves. In this context, the non-proliferation and arms control regimes are in crisis [5]. The last remaining treaty to reduce and limit nuclear weapons between U.S. and Russia, the New

Start, expired in February 2026. Both atomic powers are radicalising their policies, i.e. Russia incorporated in 2024 the potential use of tactical nuclear weapons into its military doctrine in response to conventional attacks against Russian territory, while the U.S. National Security Strategy published in 2025 proposes resuming testing of atomic bombs and deploying new anti-ballistic missile systems in space, among others. Moreover, several countries are considering acquiring nuclear weapons capabilities and joining the group of nine atomic states. These developments represent an additional factor that may contribute to the normalization of attacks against nuclear installations.

Certain states have developed military planning scenarios in which specific civilian and energy infrastructures are considered strategic targets, with the objective of disrupting adversary capabilities and ground movements. Such scenarios also include civilian nuclear facilities, which, if severely damaged during large-scale conflicts, could result in radioactive releases, further escalating the strategic dimension of a conflict with large-scale population evacuations and transboundary impacts on public health and environment.

IMPLICATIONS AND POSSIBLE ACTIONS

The consequences of the growing entanglement between nuclear facilities and armed conflicts extend far beyond technical considerations. They involve issues of global concern and highlight both the absence of an international non-aggression treaty or convention specifically aimed at protecting nuclear installations during armed conflicts, as well as the urgent need to adapt and develop dedicated IAEA nuclear safety and security standards in wartime contexts [1].

The 1977 Additional Protocol I, which supplements the 1949 Geneva Conventions concerning international armed conflicts addresses through article 56 restrictions on the protection of facilities with potential impact to population, but it does not explicitly address attacks against nuclear installations. In this regard, the Russian Federation withdrew in 2019 its previous ratification of the Protocol in 1989, while the U.S. never ratified that Protocol and its Law of War Manual of the Department of Defense updated in 2023, rejects the provisions contained in Article 56. The 1979 IAEA Convention on the Physical Protection of Nuclear Material and Nuclear

³ Extreme examples are the Karachi NPP in Pakistan with 8.2 million people living within 30 Km of the plant, or the populated vicinity of the seven reactors of the Qinshan NPP in China.



Figure 4. Four reactor units at the Emirati Barakah NPP.



Figure 5. Iranian Bushehr NPP.

Facilities, which criminalises illicit trafficking and sabotage of nuclear materials or nuclear facilities, does not address military attacks to nuclear facilities. These rules remain insufficient and ambiguous conferring potential legal vacuum whereby attacks on nuclear installations may not be formally classified as illegal under international law.

The adoption and ratification of a specific global convention or treaty prohibiting attacks against nuclear installations is therefore an urgent matter. The IAEA has made unsuccessful attempts towards securing such prohibition, recently at IAEA General Conferences and at the Nuclear Non-Proliferation Treaty Review Conference. Such convention could establish provisions applicable during armed conflicts, including the creation of security zones around nuclear facilities, the placement of reactors under international oversight and the involvement of the IAEA in supporting the operation of reactors and spent fuel facilities. Given the current international disorder, it is conceivable that one or more states could violate such provisions during an open confrontation. Nevertheless, the existence of internationally ratified norms would contribute to limiting the normalization of attacks against nuclear installations and to delegitimize the justification of military actions against such facilities in future crises or other regions of the world.

However, there are also existing international agreements that provide useful elements that could be drawn, i.e. the 1988 India-Pakistan 'Non-nuclear Aggression Agreement Treaty' and the 1991 'Brazilian-Argentine Agency for Accounting and Control of nuclear materials (ABACC)', the unique binational organisation for nuclear safeguards.

In relation to nuclear safety and security standards, the IAEA established -following the outbreak of the war in Ukraine- seven pillars for ensuring nuclear safety and security to assess risks in war contexts. They are: physical integrity of all facilities; full functioning of all safety and security systems; working

conditions and ability of operators to perform their duties and make decisions without undue pressure; ensuring external power supply; ensuring logistical supply and transportation to the site; effective radiological monitoring and emergency preparedness; and reliable communication with the nuclear regulator.

Since it was not possible to establish a demilitarised zone around Zaporizhzhia NPP, the UN Security Council endorsed in May 2023 the five concrete principles established by the IAEA, essential for averting an accident at the Zaporizhzhia plant. They are: no attacks of any kind from or against the plant, in particular directed to reactors, irradiated fuel storage, critical infrastructure or personnel; the plant cannot be used as storage or seating for heavy weaponry or military personnel that could be used for an attack from the plant; the external power supply cannot be placed at risk and must be secured at all times; all structures, systems and components essential to safety must be protected from attack or sabotage; and no action that undermines these principles must be taken.

Those seven pillars of nuclear safety and security, together with those five concrete principles, constitute the principal foundation for the IAEA to further develop safety and security standards for nuclear installations during armed conflicts. In addition, the technical assessments conducted at the Slovenian Krško NPP during the 1991 Slovenian Independence war, which addressed reactor subcriticality, fuel cooling, containment integrity, and radiological inventory, could be taken into consideration. In view of the referred aggressions to nuclear installations, the nuclear security standards should be extensively reviewed. In this regard, lessons can be drawn from the series of Nuclear Security Summits⁴ held in the past, aimed to prevent nuclear terrorism attacks by incorporating military and intelligence expertise into nuclear security practice.

⁴ Four high-level Nuclear Security Summits (2010-2016) strengthened national nuclear security regulations and the implementation of international nuclear security conventions.

The present uncertain international context provides also the opportunity for extending the IAEA standards to cover those identified challenges. The IAEA Safety Standards Committee (CSS) is building on all mentioned foundations to adapt and apply existing standards, while the European Nuclear Safety Regulators Group (ENSREG), including the Spanish Nuclear Regulator (CSN), is pursuing complementary efforts in the same direction.

COMPENDIUM

The safety situation at Zaporizhzhia NPP is deteriorating and an accident cannot be excluded. Time is working against and there is no room for complacency or assumption that its current situation is stable. The IAEA continues calling for urgent action to prevent such an outcome, and the present failure by the international community to adopt effective measures, undermines the protection of the plant and risks that attacks on nuclear facilities during armed conflicts become increasingly normalized.

While there is uncertainty about how the current wars will unfold, it is evident that the trend of treating civilian nuclear infrastructures as military targets is gaining ground. This new role for nuclear facilities, transformed into platforms onto which strategic military objectives are being projected, represents a clear paradigm shift that cannot be ignored. It threatens the peaceful use of nuclear energy and poses the serious challenge of strengthening the nuclear safety and security of civilian nuclear infrastructures. If conventional nuclear fission power should continue contributing to the electricity generation and limiting global climate change patterns, the challenge for the international community is to ensure that civilian nuclear facilities remain strictly outside the scope of armed conflicts, maintaining in that way the credibility of nuclear power.

The present disarray of the international legality offers neither a pathway for the development and ratification of a global non-aggression convention that addresses the current legal vacuum, nor the certainty of effectively implementing the new nuclear safety and security standards. Even though those goals remain gloomy as long as wars continue and nuclear proliferation is on the rise, an additional push for addressing both challenges would be their inclusion into any expected or ongoing peace negotiations, allowing the IAEA to contribute to the development, implementation and verification of future regulatory frameworks.

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