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Nuclear Facilities in Times of Crisis

SUMMARY

Novel and increasingly intense global crises, like Russia's invasion of Ukraine, are stressing nuclear facilities in new ways. This paper evaluates existing strategies for reducing the risk of catastrophe at nuclear facilities during armed conflict and natural disasters and recommends additional steps that governments and international institutions should take to ensure that facilities are prepared to withstand future crises.

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BUILDING A SAFER WORLD

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Foreword by Ernest J. Moniz

For the first time, an invading army has occupied an operating civilian nuclear facility. Russia's invasion of Ukraine and seizure of the Zaporizhzhia Nuclear Power Plant (ZNPP) is a stark example of the new wave of risks that nuclear facilities can face. Since the Russian military took over the plant in March 2022, most of ZNPP's staff have fled and those who remain have withstood threats to their well-being. Nearby fighting has crippled the site, raising fears of a nuclear accident that would harm hundreds of thousands of people in Ukraine and beyond. Critical infrastructure that provides the water and electricity required for safe operations has been severely damaged, necessitating makeshift fixes that, while holding for now, are not long-term solutions. The war has forced ZNPP, and several other Ukrainian facilities, to grapple with the reality that operating in a warzone is simply beyond the scope of traditional safety and security planning. Growing global instability coupled with growing interest in nuclear energy expansion suggests that Ukraine will not be the last country to have a nuclear facility in the line of fire, so fresh thinking about how to best prevent a nuclear catastrophe during armed conflict is more urgent than ever.[1]

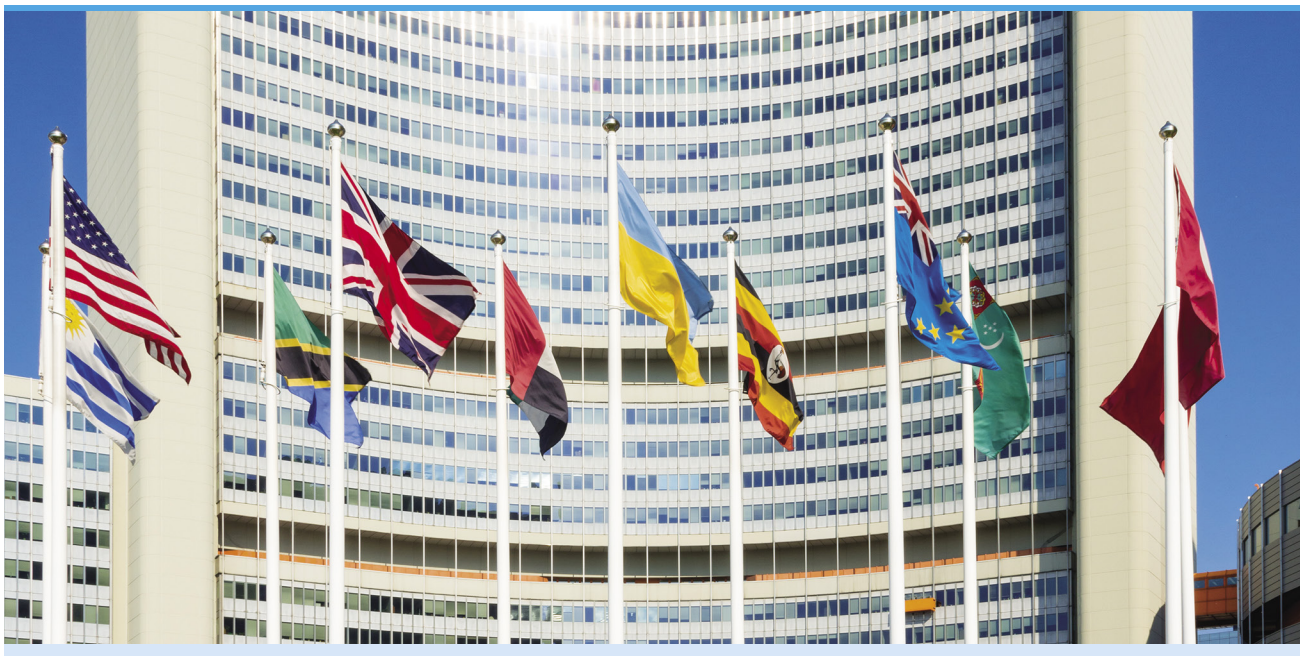
Armed conflict is not the only kind of crisis that threatens nuclear facilities. The ever-worsening scourge of climate change is bringing floods, wildfires, and other natural disasters that can interfere with site operations. This has an immediate impact on safety posture, and secondary effects that also put great stress on security infrastructure and culture.

Catastrophic damage to nuclear facilities, whether accidental or intentional, could release large amounts of radiation, leading to severe economic damage and humanitarian disaster. In cases where facilities house weapons-usable nuclear materials—highly enriched uranium (HEU) and separated plutonium—crisis scenarios increase the risk of those materials falling into the hands of non-state actors.

The need to keep nuclear facilities resilient to extreme conditions becomes more urgent as nuclear facilities become more prevalent. In 2023, at the COP28 climate conference in Dubai, 25 countries committed to tripling global nuclear energy capacity by 2050. This was just the latest example of the remarkable ambition that governments and industry have shown for increasing the role that nuclear energy plays globally. If countries are to achieve their goals, it will require an unprecedented expansion of nuclear installations around the world. Civilian nuclear technology brings many great benefits, but it also comes with particular challenges that must be properly managed to ensure safety and security in dynamic environments. Now is the time for all stakeholders to take this responsibility seriously by making resiliency an intrinsic part of planning for all nuclear facilities.[2]

[1] *Climate and Social Stress: Implications for Security Analysis* (National Academies Press eBooks, 2013), https://doi.org/10.17226/14682.

[2] Although natural and human-made crises affect all parts of the nuclear fuel cycle, this paper only focuses on civilian nuclear facilities. NTI believes that further research is needed to study the effect of crises on military nuclear materials and facilities.



A Plan for Action

Neither human-made nor naturally occurring disasters are new problems for nuclear facilities. Yet, not all nuclear facilities have incorporated adequate crisis-response measures into safety and security planning, leaving them vulnerable.[3] Today, the risk of a nuclear catastrophe is compounded as novel and increasingly intense crises stress established systems and protocols, and increasing interest in nuclear energy from embarking countries across the globe creates the possibility of new facilities in unpredictable environments.

The stakes are high because the ramifications of a security lapse at a nuclear facility can be devastating. At facilities with nuclear reactors or spent fuel, the risk is of a release of radiological material that would bring mass panic, evacuations, and possibly the end of nuclear as a practical tool for reliable, low-carbon emitting energy. Facilities that house HEU and plutonium present a different level of risk with even greater consequences. Crises can create chaos and lapses in normal security posture, presenting opportunities for theft. Just kilogram quantities of these weapons-usable materials falling into the hands of criminals or terrorists would allow them to develop a nuclear weapon capable of mass destruction. Crises also create distractions and vulnerabilities that produce opportunities for cyber-attacks on digital systems.

International laws, regional accords, and domestic policies have formed a foundation of norms that have reduced risks posed to nuclear facilities around the world for decades. Given the changing threat environment, updates to the current system are needed to reduce risks into the future. This paper examines existing mechanisms related specifically to armed conflict and natural disasters—two categories of crises that

[3] For more, see *Prioritize Nuclear Security in Times of Heightened Risk*, https://www.ntiindex.org/recommendation/prioritize-nuclear-security-in-times-of-heightened-risk/.

can have outsized impact on the security of nuclear facilities[4]—and recommends actions for governments and international institutions to better protect facilities from the threats of today and tomorrow.

The many recommendations in this paper range from initiatives that can be accomplished unilaterally, to longer-term goals that often require bilateral, regional, or broader multilateral agreement. Following are the four highest priority recommendations that countries can start taking action on immediately:

- **To prevent attacks on nuclear facilities,** establish clear political and legal commitments that protect nuclear facilities during armed conflict.
  - Too many countries hold ambiguous, hedged positions on the legality and viability of targeting nuclear facilities. One simple and straightforward way to help remedy this is to formally and universally endorse the International Atomic Energy Agency's (IAEA) seven essential pillars of nuclear safety and security, which can be done through national statements and declarations.
- **To make nuclear facilities more resilient to crisis scenarios,** establish whole-of-government response and contingency plans for a broad array of possible situations, including armed attacks and extreme natural disasters.
  - Exercises should be held regularly to practice and hone capabilities, maintaining high levels of inter-agency coordination and collaboration with facility operators and local communities.
- **To prevent a crisis at a nuclear facility from becoming a global calamity,** commit to supporting and pursuing only nuclear energy technologies that avoid using weapons-usable material.
  - HEU and separated plutonium introduce enormous risks, and they are not required to meet modern nuclear energy demands. Countries should commit to avoiding their use and eliminating stockpiles where they exist.
- **To plug gaps and promote a more secure future,** use the IAEA as a vehicle to develop an international code of conduct for dealing with armed conflict near nuclear facilities.
  - This can be a quicker and more attractive option than trying to establish new legal frameworks or amending existing treaties. The IAEA can get started by producing recommendations and conducting peer reviews focused on maintaining security during crises. This effort should not divert attention or resources from the ongoing crisis in Ukraine.

[4] This paper defines crises as events that threaten the core mission of an organization and its ability to meet its goals, occur within a limited response timeframe, and are unexpected or unforeseen. For more on this definition, see Geoffrey Chapman et al., *Nuclear Security in a Time of Crisis*, (Stimson Center, October 5, 2022), https://www.kcl.ac.uk/csss/assets/nuclear-security-in-times-of-crisis-handbook.pdf.

Credit: Alexander Ermochenko / REUTERS

A Russian all-terrain armored vehicle is parked outside the Zaporizhzhia Nuclear Power Plant during a visit of the IAEA in September 2022.

Existing Mechanisms Related to Nuclear Terrorism and Nuclear Security During Armed Conflict

National Commitments

Governments have long debated the legality of attacks on nuclear facilities by state and non-state actors. Over time, they have developed a set of legal and political norms and commitments intended to deter such attacks and delineate obligations to protect nuclear facilities.

International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT)

ICSANT is the primary treaty criminalizing acts of nuclear terrorism. The treaty defines nuclear terrorism as:

> "Anyone who uses in any way radioactive material or a device, or uses or damages a nuclear facility in a manner which releases or risks the release of radioactive material...with the intent to compel a natural or legal person, an international organization or a State to do or refrain from doing an act."[5]

[5] International Convention for the Suppression of Acts of Nuclear Terrorism, art. 2, 2445 U.N.T.S. 44004, A/RES/59/290 (April 13, 2005), https://treaties.un.org/doc/source/RecentTexts/English_18_15.pdf.

It also covers anyone who "demands unlawfully and intentionally radioactive material, a device or a nuclear facility by threat, under circumstances which indicate the credibility of the threat, or by use of force." This definition does not apply to the Russian military's actions in Ukraine because the treaty excludes activities of armed forces during conflicts. However, the ongoing involvement of Russian-supported non-state actors raises legal uncertainties that may require adjudication.

Geneva Conventions

A key legal mechanism for discouraging or criminalizing certain kinds of state attacks on nuclear facilities is International Humanitarian Law (IHL). IHL seeks to regulate the conduct of war or govern the way warfare is conducted by state actors. The 1977 Additional Protocol I to the Geneva Conventions is a part of IHL that addresses issues related to attacks on nuclear facilities.[6] Protocol I not only forbids attacks on civilians and civilian infrastructure, which could be understood to cover civilian nuclear power plants and their employees, but it also establishes special protections and implies broader requirements for protecting these facilities.[7]

- Article 51, "Protection of Civilian Population," prohibits indiscriminate attacks against civilians unless they are directly involved in hostile activities. It also prohibits warring parties from engaging in or threatening acts of violence intended to spread terror among civilians.[8]
- Article 55, "Protection of Natural Environment," prohibits methods or means of warfare by fighting parties that may cause widespread, long-term, and severe damage to the natural environment.[9]
- Article 56, "Protection of Works and Installations Containing Dangerous Forces," calls for the protection of works or installations like dams, dykes, and nuclear electrical generating stations during armed conflict. It bars aggressor states from attacking infrastructure if such an attack would cause the release of dangerous forces, resulting in the loss of civilian lives, even if such an attack would fulfill a military objective. The article, however, includes important caveats to these prohibitions. For example, the protection for installations, including nuclear electrical generating stations, does not apply if the facilities involved directly support military operations and destroying the facility itself is the only option to terminate such support. The Geneva Conventions' Additional Protocol II contains a version of Article 56 that omits the limitations on the protection of works or installations that exist in Protocol I.[10]
- Article 57, "Precautions in Attack," states that all parties involved in armed conflict should always take all the necessary precautionary steps to spare civilians and civilian objects and avoid launching attacks that have the potential to cause civilian casualties and destroy civilian objects. If an action must be carried out to gain military advantage, the parties should try to choose options that will

[6] Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, [Protocol I] opened for signature Dec. 12, 1977, 1125 UNTS 3, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977.

[7] For Protocol I's definition of a civilian object, see "Article 52—General protection of civilian objects," https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-52?activeTab=undefined.

[8] Protocol I, art. 51, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-51?activeTab=undefined.

[9] Protocol I, art. 55, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-55.

[10] Protocol I, art. 56, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-56.

least impact civilians and their objects. Also, warring parties should give adequate advanced warning of attacks to avoid or minimize civilian casualties.[11]

- Article 58, "Precautions against the Effects of Attacks," requires that parties to the treaty "take the other necessary precautions to protect the civilian population, individual civilians and civilian objects under their control against the dangers resulting from military operations." In its commentary on articles 57 and 58 of Protocol I, the International Committee for the Red Cross emphasized the relevance of facilities "entitled to special protection" such as nuclear facilities.[12]

The Geneva Conventions only explicitly reference certain types of nuclear facilities. However, a firefight near a nuclear facility or a deliberate act of sabotage that leads to a nuclear disaster, causing long-term, widespread, indiscriminate environmental and humanitarian harm (including the dispersion of nuclear material) could easily be interpreted as a violation of Protocol I. As of 2024, 174 countries have ratified Protocol I, but five countries with nuclear facilities—the United States, Israel, Iran, Pakistan, and India—have not. Turkey, which is in the final stages of building its first nuclear power plant, also has not ratified Protocol I. Significant gaps also exist in Protocol I's language that leave nuclear facilities exposed. For example, Article 56 only applies to electrical generating stations.

United Nations Security Council Resolution (UNSCR) 1540

UNSCR 1540, unanimously approved by the UN Security Council in 2004, is another legal mechanism that contains language related to protecting nuclear facilities. The resolution creates a legal requirement for all UN Member States to provide "appropriate effective" security and accounting for stocks of nuclear weapons and weapons-usable materials in their possession. Although it does not define "appropriate effective," it is reasonable to say this should include a nuclear facility's obligation to prevent nuclear theft or sabotage during organizational crises, a primary risk of degraded security conditions during an armed conflict or natural disaster.

Regional Commitments

Governments have also negotiated legally binding regional prohibitions on attacking nuclear facilities. Although nuclear facilities were not widely prevalent across Africa when Israel attacked Iraqi nuclear installations in 1981, African governments were alarmed enough by the attack to take decisive preventative action.[13] The Pelindaba Treaty, which opened for signature in 1996 and establishes a nuclear-weapon-free zone (NWFZ) in Africa, prohibits parties from taking, assisting, or encouraging "any action aimed at an armed attack by conventional or other means against nuclear installations."[14] Of the five NWFZs around the world, this is the only one that includes a provision pertaining to attacks on nuclear facilities.

[11] Protocol I, art. 57, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-57.

[12] Protocol I, art. 58, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-58.

[13] Oluyemi Adeniji, *The Treaty of Pelindaba on the African Nuclear-Weapon-Free-Zone* (United Nations Publications UNIDIR, 2002), https://unidir.org/wp-content/uploads/2023/05/the-treaty-of-pelindaba-on-the-african-nuclear-weapon-free-zone-297.pdf.

[14] "African Nuclear Weapon-Free-Zone Treaty (Pelindaba Treaty)," opened for signature April 11, 1996, https://www.iaea.org/publications/documents/treaties/african-nuclear-weapon-free-zone-treaty-pelindaba-treaty.

In addition to legally binding treaties, countries have also agreed to bilateral political commitments prohibiting attacks on civilian nuclear facilities. After a period of escalating tension between India and Pakistan in the 1980s, the two countries agreed not to attack each other's nuclear facilities. Beginning January 1, 1992, and every year thereafter on the same date, the two countries have exchanged a list of nuclear facilities that both sides agree to not attack, even in the event of hostilities. The process has continued without interruption, irrespective of turbulent times. This bilateral agreement is the only one of its kind.

International Dialogue

International organizations and fora have also supported prohibiting attacks against nuclear facilities in various non-binding resolutions and discussions. IAEA Member States' concerns with radiological consequences from attacks on nuclear facilities have led them to adopt resolutions during the IAEA's annual General Conference (GC) in 1983, 1985, 1988, and 2009 that supported the protection of civilian nuclear facilities.[15] The deliberations around these non-binding resolutions are private, which means individual government positions on this issue are unclear. These final resolutions do, however, reflect the sustained view of IAEA Member States over decades that armed attacks on civilian nuclear facilities should be outlawed.

Discussions about the implications of attacks on nuclear facilities have also taken place during review conferences for the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Security for nuclear facilities is not explicitly part of the NPT, but the right to use nuclear energy for peaceful purposes is one of its fundamental pillars. The potential for state targeting of nuclear facilities to infringe on that right is not an issue that states parties have paid much attention to until recently. For example, Action 64 from the 2010 NPT Review Conference called upon all Member States to abide by the resolution adopted at the 2009 IAEA GC, "Prohibition of All Armed Attacks Against Nuclear Installations Devoted to Peaceful Purposes Whether Under Construction or in Operation." In addition, although the 2022 NPT Review Conference failed to produce a consensus outcome document, the draft document developed expressed grave concerns about attacks or threats of attacks on civilian nuclear facilities.[16]

Additional conversations about attacks on nuclear facilities have taken place within other fora. Weeks after Russia began assaulting Ukrainian nuclear facilities in 2022, the IAEA hosted the Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material (CPPNM). This inaugural review of the Amended CPPNM, which legally obligates countries to physically protect nuclear facilities, was one of the first high-level events where governments responded to the crisis unfolding at Ukrainian nuclear facilities. During the meeting, many governments spoke out against Russia's actions and endorsed an IAEA Information Circular released during the review highlighting "concern over the nuclear safety and security risks that have been caused by Russia's invasion of Ukraine."[17]

[15] Ali Alkış, *Nuclear Security During Armed Conflict* (Stimson Center, November 15, 2022), https://www.stimson.org/2022/nuclear-security-during-armed-conflict/.

[16] "Tenth Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Draft Final Document," NPT/CONF.2020/CRP.1/Rev.2 (August 25, 2022), https://reachingcriticalwill.org/images/documents/Disarmament-fora/npt/revcon2022/documents/CRP1_Rev2.pdf.

[17] "Communication dated April 1, 2022 received from the Delegation of the European Union to the International Organizations in Vienna concerning a Joint Statement to the Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material," IAEA Doc. INFCIRC/987, April 2022, https://www.iaea.org/sites/default/files/publications/documents/infcircs/2022/infcirc987.pdf.

International Institutions

As the international organization responsible for nuclear safety and security, the IAEA has played a critical role in aiding nuclear facilities, regulators, and governments during crises. For example, when the COVID-19 pandemic interfered with nuclear operations around the world[18] the IAEA created the Nuclear Power Plant Operating Experience (OPEX) Network, which allowed nuclear operators to share information on COVID-19 risk mitigation and the impact of the pandemic on plant performance.

In response to the crisis in Ukraine, the IAEA has undertaken an unprecedented effort to avoid a nuclear disaster—going so far as to send teams of IAEA employees to nuclear facilities in the middle of a hot war. These teams are serving an important role by advising operators on nuclear safety, security, and safeguards, increasing the political cost of attacking a Ukrainian nuclear facility, and keeping the world's attention on the dangerous situation at these facilities.

The IAEA has also coordinated providing supplies needed for nuclear safety and security implementation throughout the Russian-Ukrainian war. Through the IAEA's Response and Assistance Network, 12 countries responded to Ukraine's request for equipment and 11 countries donated funds to assist with nuclear safety, security, and safeguards in Ukraine.[19] The agency has also provided regular updates on nuclear safety and security conditions in Ukraine, helping share vital information to governments and publics around the world.[20]

In addition to advocating for the safety and security of nuclear facilities within Ukraine, the IAEA has also capitalized on the moment of increased attention on nuclear security to develop and promote nuclear security measures more broadly. On March 2, 2022, at an IAEA Board of Governors meeting, IAEA Director General Rafael Mariano Grossi introduced the "seven indispensable pillars of nuclear safety and security."[21] These pillars, which have been endorsed by many governments, comprise common-sense measures that all countries with nuclear facilities should fulfill, including during times of physical conflict.

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 fulfill 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;

[18] Chris Hobbs, Nickolas Roth, and Daniel Salisbury, "Security Under Strain? Protecting Nuclear Materials During the Coronavirus Pandemic," *RUSI Journal* 166, no. 2 (February 23, 2021): 40–50, https://doi.org/10.1080/03071847.2021.1937302.

[19] "IAEA Director General's Introductory Statement to the Board of Governors," September 12, 2022, https://www.iaea.org/newscenter/statements/iaea-director-generals-introductory-statement-to-the-board-of-governors-12-september-2022.

[20] IAEA Press Releases, https://www.iaea.org/news?type=3243.

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

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.

Little more than a year later, Director General Grossi expanded on the pillars when he introduced five concrete principles of nuclear safety and security at ZNPP to the UN Security Council:[22]

1. There should be no attack of any kind from or against the plant, in particular targeting the reactors, spent fuel storage, other critical infrastructure, or personnel;

2. ZNPP should not be used as storage or a base for heavy weapons (i.e., multiple rocket launchers, artillery systems and munitions, and tanks) or military personnel that could be used for an attack from the plant;

3. Off-site power to the plant should not be put at risk. To that effect, all efforts should be made to ensure that off-site power remains available and secure at all times;

4. All structures, systems, and components essential to the safe and secure operation of ZNPP should be protected from attacks or acts of sabotage;

5. No action should be taken that undermines these principles.

Although not explicitly mentioned in the seven pillars or five principles, Director General Grossi has also extensively addressed the precarious situation of water access and reactor cooling at ZNPP, which are necessary for safe operation. Amid reports that Russia may attempt to restart one or more of the reactors, the IAEA has played a vital role in highlighting the importance of keeping the reactors in a state of shutdown for the safety and security of the site.

Industry Organizations

Organizations that provide education and training for industry, like the World Institute for Nuclear Security (WINS) and World Association of Nuclear Operators (WANO), play an important role in helping nuclear operators prepare for crises. WINS provides technical guidance on how to protect against threats, including a report on "Securing Radioactive Sources During War Time and Violent Civil Unrest" with clear applications for nuclear facilities.[23] WINS also published a book documenting the experiences of nuclear operators during the war in Ukraine with valuable lessons from the frontlines of the crisis.[24] WANO conducts safety peer reviews and helps develop and share root cause analysis and lessons learned to prevent similar security

[22] "IAEA Director General Statement to United Nations Security Council," May 30, 2023, https://www.iaea.org/newscenter/statements/iaea-director-general-statement-to-united-nations-security-council-30-may-2023.

[23] Bethany Woodward, *Securing Radioactive Sources During War Time and Violent Civil Unrest*, World Institute for Nuclear Security, 2023, https://www.wins.org/document/securing-radioactive-sources-during-war-time-and-violent-civil-unrest/.

[24] World Institute for Nuclear Security, *WINS Launches Voices of Ukraine Book on Impact of War on Nuclear Workers and Facilities*, May 16, 2023, https://www.wins.org/wins-launches-voices-of-ukraine-book-on-impact-of-war-on-nuclear-workers-and-facilities/.

incidents from recurring. During the most serious moments of COVID-19, WANO published articles on how to maintain human performance at nuclear power plants during the pandemic.[25]

Eliminating the Most Concerning Nuclear Materials

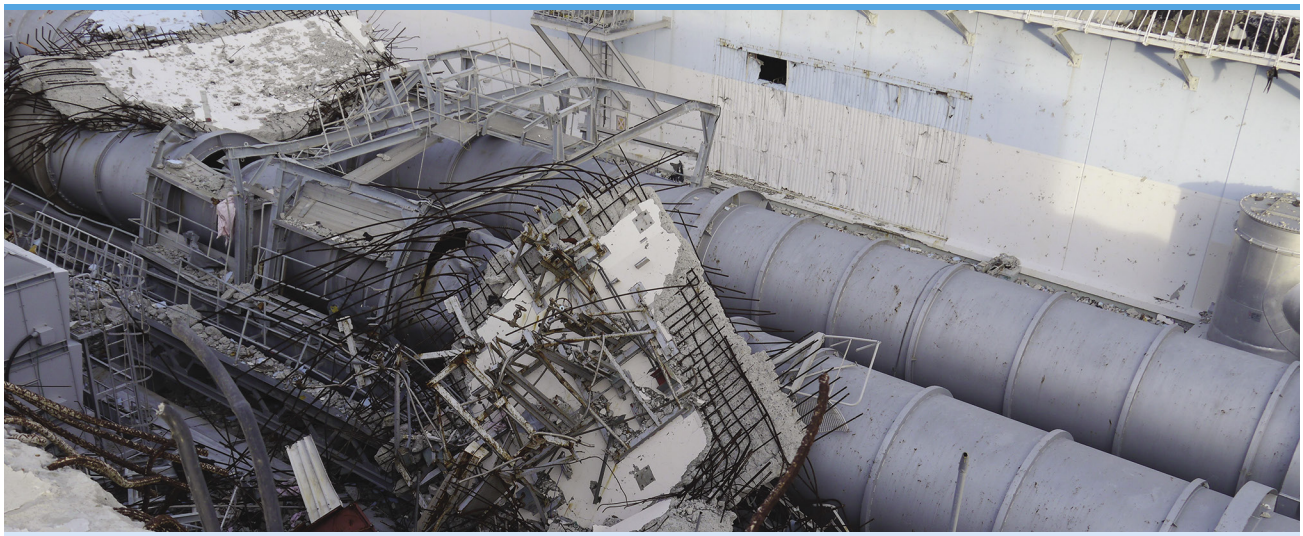
The presence of weapons-usable nuclear materials, namely HEU and separated plutonium, significantly exacerbates the security challenges and vulnerabilities of a facility. These materials could not only spark a radiological incident but, if commandeered, be used to fashion a nuclear weapon. Prior to 2012, several Ukrainian facilities stored HEU, but it was all removed through a collaborative effort involving Ukraine, the United States, Russia, and the IAEA. Some of these facilities have been the target of Russian attacks since 2022, putting the importance of the Ukrainian government's decision in a new light.[26] Avoiding the use of HEU and separated plutonium at civilian facilities is a common-sense best practice that mitigates risk during times of crisis.

The IAEA estimates that it would take only 25 kilograms of HEU or eight kilograms of separated plutonium to make a nuclear bomb.[27] Although most nuclear facilities across the world avoid these materials, recent trends in separated plutonium stockpiles are concerning. Global civilian inventories of separated plutonium grew by 55 metric tons (17.4%) between 2012 and 2023. This can be almost entirely attributed to commercial reprocessing campaigns in five countries: France, India, Japan, Russia, and the United Kingdom. Several next-generation reactor designs call for separated plutonium fuels and, if deployed, would further expand the size and scope of global stockpiles.

[25] "WANO Review," https://www.wano.info/resources/wano-review.

[26] "Fact Sheet: Ukraine Highly Enriched Uranium Removal," The White House, March 27, 2012, https://obamawhitehouse.archives.gov/the-press-office/2012/03/27/fact-sheet-ukraine-highly-enriched-uranium-removal.

[27] International Atomic Energy Agency, *IAEA Safeguards Glossary: 2021 Edition*, International Nuclear Verification Series, No. 3, https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf, 2023, p. 23.



Credit: IAEA / Alamy Stock Photo

Debris in front of the remains of Unit 4 upper levels at the Fukushima Daiichi Nuclear Power Station December 18, 2012 in Okuma, Japan. The plant suffered a catastrophic meltdown in March 2011.

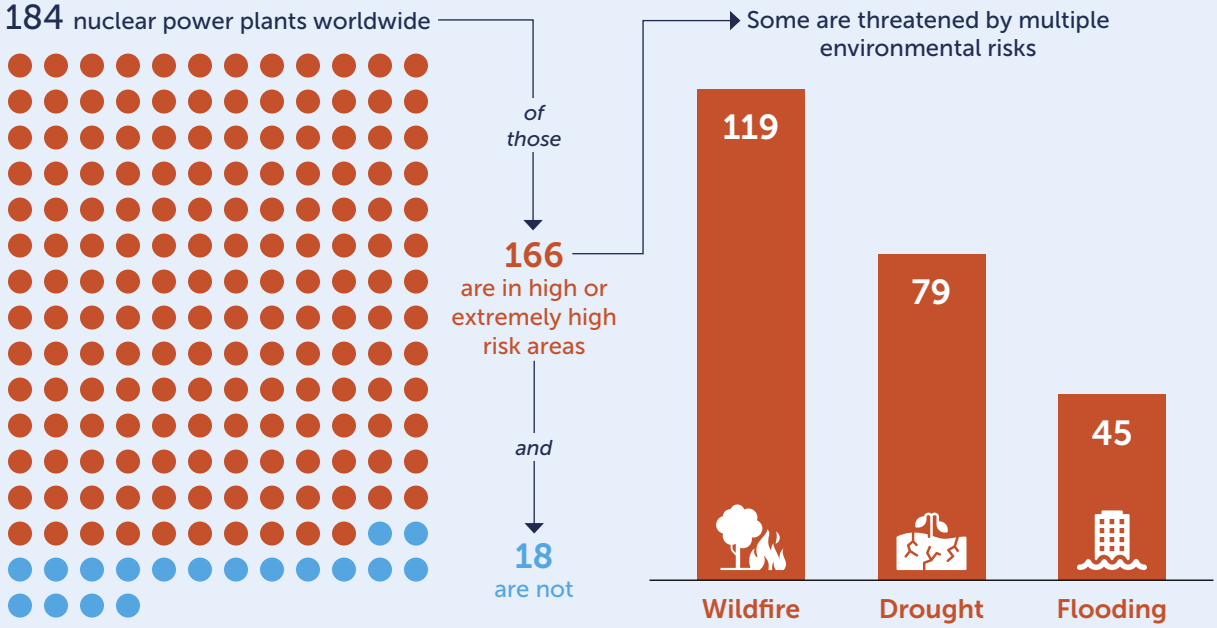
Existing Mechanisms Related to Environmental and Natural Disasters

Although the immediate and difficult-to-control nature of armed conflicts makes planning for their effects particularly important, natural disasters and health crises also merit careful consideration. Attention to these types of crises has increased since the 2011 Tōhoku earthquake off the coast of Japan created a tsunami that hit the Fukushima Daiichi Nuclear Power Station and led to widespread damage at the facility and the meltdown of multiple reactors. It is possible to build nuclear facilities that are resilient to many natural disasters—but it requires thoughtful and proactive planning.

Frequently, and for good reason, crisis response and even post-crisis analyses focus on the safety of the site and the surrounding public. However, the potential for natural disasters to compromise the security of nuclear facilities is thoroughly documented and deserves to be included as well. Several case studies show the concrete ways these events can impair security and the enormous risks that can result. Responding to a safety crisis can often feel like an all-encompassing task, requiring whatever resources, focus, and extraordinary measures necessary to neutralize the risk. However, overlooking standard security protocols to attend to a safety crisis opens facilities to serious vulnerabilities, as demonstrated by the following examples.

Most Nuclear Power Plants Are in Areas Facing Climate Stress

90% are in locations where the risk of wildfire, drought, or flooding is high or extremely high.*



*Wildfire risk are areas rated "high" by Leonard et al (2017); drought risk are areas labeled "high" or "extremely high" by Kuzma et al (2023); coastal storm surge or tsunami risk are areas where there is a 1 in 100 year chance of a 2 m or greater water level as estimated by Muis et al (2016) for storm surges or Davies et al (2017) for tsunamis.

Sources: Leonard et al (2017), Wildfire Hazard Layer Technical Basis and Demonstration; Kuzma et al (2023), Technical Note, Aqueduct 4.0: Updated Decision-Relevant Global Water Risk Indicators, https://doi.org/10.46830/writn.23.00061; Muis et al (2016) "A global reanalysis of storm surges and extreme sea levels," Nature Communications, https://doi.org/10.1038/NCOMMS11969; Davies et al (2017), A global probabilistic tsunami hazard assessment from earthquake sources, https://doi.org/10.1144/SP1456.1146.

Droughts and Rising Water Temperature

Water is essential to the safe functioning of nuclear facilities, particularly power facilities that rely on water for cooling. On average, nuclear power requires approximately 1,100 gallons of water per megawatt hour of electricity produced, slightly more than coal, concentrated solar, and biomass power.[28]

Nuclear power facilities need water for two main reasons: to produce electricity through a steam generator (a process similar to other thermal power sources) and to cool the reactor and spent fuel. Droughts that limit water availability can prevent the safe operation of nuclear reactors. An increase in water temperature

[28] Gary Vine, *Cooling Water Issues and Opportunities at U.S. Nuclear Power Plants*, U.S. Department of Energy, December 1, 2010, https://doi.org/10.2172/1004239.

presents similar challenges, as it takes a greater volume of warmer water to achieve required cooling. Fortunately, both drought and rising water temperature are challenges that develop gradually and can be forecasted, and countries can take steps to prevent such scenarios from developing into serious safety or security incidents.

Floods and Wildfires

Floods and wildfires present risks to the physical integrity of a site's critical infrastructure and challenge its ability to maintain adequate staffing.[29] Unlike droughts and rising water temperatures, these emergencies are not always as slow to develop, and thus require different strategies to reduce risks. These strategies include taking floods and wildfires into account through site-specific assessments of facility designs for protecting against natural disasters. Based on site-specific circumstances, mitigation tactics can include physical barriers, redundant safety equipment, and comprehensive emergency and recovery plans emphasizing security that are documented, well-understood by all staff, and tested. The most prominent example of this type of emergency is the meltdowns at Fukushima in 2011. A magnitude 9.1 earthquake knocked out electrical lines that powered cooling equipment, while flooding from the resulting tsunami inundated and disabled backup generators. Experts have learned numerous lessons from this incident that have been and continue to be important for improving the safety and security of reactors around the world.[30]

Pandemics

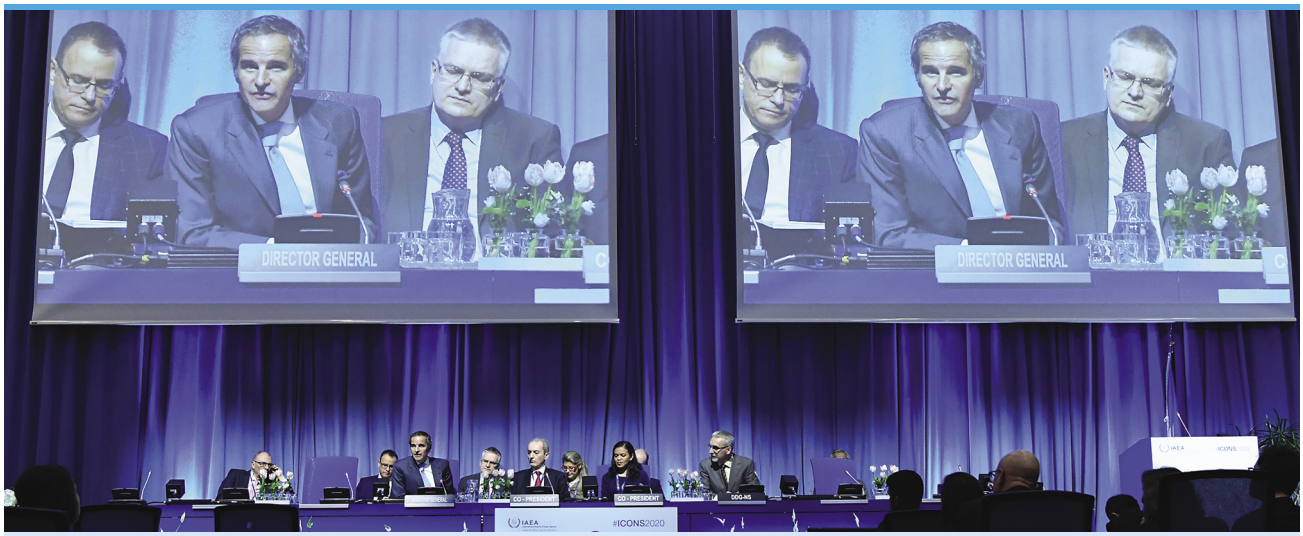
Although many nuclear facilities have built-in contingency planning for pandemics, the first international test came during COVID-19. In many ways, the challenges for the nuclear sector mirrored those across the global economy: maintaining adequate staffing levels, dealing with a snarled supply chain, and coping with lower product demand. But for nuclear operators, the safety and security of facilities was at stake. Cascading effects from maintenance delays and staffing shortages must be taken into account and planned for.

The IAEA has compiled a resource for Member States with lessons learned from COVID-19 and guidance on good practices when dealing with pandemics. These practices start with nuclear operators and regulators creating effective business continuity plans and proactively identifying essential workers, functions, and measures to mitigate risks. The IAEA also recognized the need to integrate information technology and tools that allow for remote work in appropriate circumstances. Although many essential tasks at nuclear facilities must be completed in person, remote tools are essential for keeping workers connected, engaged, and productive.[31]

[29] For more on reducing security risks during wildfires, see: Chapman et al., *Nuclear Security in a Time of Crisis*.

[30] *Lessons Learned from the Fukushima Nuclear Accident for Improving Safety of U.S. Nuclear Plants*, National Academies of Sciences, Engineering, and Medicine, July 2014, https://nap.nationalacademies.org/resource/18294/fukushima-brief05-PDFfromNAP-LoRes.pdf.

[31] IAEA, *Member States Experiences and Insights from Maintaining Safety, Security and Reliable Nuclear Industry Operations During the Covid-19 Pandemic*, Technical Report Series No. 491, 2023, https://www-pub.iaea.org/MTCD/Publications/PDF/DOC-010-491_web.pdf.



Credit: Dean Calma / IAEA

IAEA Director General Rafael Mariano Grossi delivers his remarks at the closing session of the International Conference on Nuclear Security ICONS 2020.

Recommendations

The above measures form a patchwork of laws, political commitments, and norms protecting nuclear facilities from various forms of crises. The new role that the IAEA has taken at nuclear facilities in Ukraine can serve as a useful model for future crises. Nevertheless, as international conflicts and natural disasters to date have demonstrated, there is considerable room for improvement. Governments and international institutions can undertake the following actions to strengthen this patchwork, mitigate risks posed by natural disasters, further discourage attacks on nuclear facilities, and help the international community be better prepared for such events in the future. This expands upon the four highest priority recommendations laid out in the action plan at the beginning of this paper.

Issue Unilateral or Joint Declarations

- All countries, especially those relying on nuclear power, should unambiguously endorse the IAEA's seven essential pillars of nuclear safety and security.
- Governments should also endorse the IAEA's five concrete principles of nuclear safety and security. Although specific to averting radiological release at ZNPP, these principles can be adapted to all nuclear facilities. Endorsements could include pledges to:
  - Not conduct an attack of any kind from or against civilian nuclear plants;
  - Not target civilian nuclear reactors, spent fuel storage, any other critical infrastructure containing radiological material, or personnel;

  - Not use a civilian nuclear facility as storage or as a base for heavy weapons or military personnel that could be used for an attack.[32]

- Governments should commit to refrain from attacking all safeguarded and operational civilian nuclear facilities, including but not limited to commercial power plants.

Develop a Code of Conduct

- Governments can enhance the security of civilian nuclear facilities and establish norms for risk reduction during conflicts by creating a specific code of conduct for such situations, with principles that can be translated into specific actionable standards. Over the longer term, governments could pursue codifying them into law.
  - Using the IAEA seven essential pillars and five concrete principles as a starting point, governments should develop a code prohibiting attacks in accordance with international laws and norms.
  - The code could outline actions that countries should take to enhance the resilience of nuclear facilities, minimizing the risk of theft and sabotage during armed conflicts.
  - The code could also highlight and specify the responsibilities of states in addressing threats beyond the scope of what nuclear operators are mandated to defend against.
  - The code and its development should not divert attention or resources from the ongoing crises at ZNPP.

Principles for Code of Conduct During Times of Conflict

Derived and modified from the IAEA's seven pillars and five principles

1. No attacks of any kind from or against civilian nuclear plants.
2. No targeting civilian nuclear reactors, spent fuel storage, any other critical infrastructure containing radiological material, or personnel.
3. No using a civilian nuclear facility as storage or a base for heavy weapons or military personnel that could be used for an attack.
4. No weaponizing nuclear or radiological materials stored at civilian facilities.
5. The physical integrity of civilian nuclear facilities must be maintained during armed conflict.

Continued on next page.

[32] "IAEA Director General Statement to United Nations Security Council," May 30, 2023.

Principles for Code of Conduct During Times of Conflict *(continued)*

6. All safety and security systems and equipment within civilian nuclear facilities must be fully functional at all times.
7. The operating staff at a civilian nuclear facility must be able to fulfill their safety and security duties and have the capacity to make decisions free of undue pressure.
8. There must be multiple secure off-site power supplies from the grid for all civilian nuclear facilities.
9. There must be uninterrupted logistical supply chains and transportation to and from civilian nuclear facilities.
10. There must be effective on-site and off-site radiation monitoring systems and emergency preparedness and response measures at all civilian nuclear facilities.
11. There must be reliable means of communication between civilian nuclear facilities, the regulator, and relevant government officials.

Strengthen Existing International Legal Frameworks

- All governments, especially those with nuclear facilities (India, Iran, Israel, Pakistan, and the United States) should ratify Additional Protocol I of the Geneva Conventions.
  - Governments that have already ratified Protocol I should reaffirm their commitment to Articles 56 and 57 through unambiguous political statements or national commitments.
- Although amending and strengthening Protocol I is likely unfeasible in the short- to medium-term, the previously mentioned code of conduct could be used as a rubric for strengthening international legal frameworks in the future.

Develop Bilateral or Regional Commitments

- All NWFZs should take lessons from the Pelindaba Treaty and consider amendments to their charters that would prohibit attacks on nuclear facilities.
- Where charter amendments are not possible, NWFZs can issue clear political commitments prohibiting attacks on nuclear facilities. This approach could also be used by regional or political blocs that fall outside of NWFZs.
- Countries with nuclear facilities, particularly those with a history of competition or rivalry, should use the non-attack agreement between India and Pakistan as a model to initiate similar accords.
  - For example, Argentina and Brazil, with their robust relations but historical military competition, could take the lead in establishing an agreement to not attack each other's nuclear facilities.

Update Domestic Policy

- Governments should develop plans to ensure the continuity of nuclear security operations during major crises. These plans should include requirements for nuclear plant operators to protect nuclear security systems and train personnel to manage severe external events, especially events with an extended duration.[33]
- This should include contingency plans to deal with crises that go beyond the design basis threat (DBT).
- Through close coordination, governments, nuclear facilities, and regulators should conduct regular exercises at nuclear facilities that are based on realistic scenarios and all operating conditions, including those that go beyond the DBT.
- Governments and operators should have contingency plans aimed at reducing risks, including options for maintaining off-site power and cooling, ensuring the effectiveness of backup systems, promptly placing spent fuel in dry casks when feasible, maintaining supply chains, protecting workers, and locating fresh and spent nuclear fuel in secure locations.
- To help prepare for potential crises, countries should establish nuclear operations centers of excellence to help train and prepare operators, regulators, first responders, and policymakers for extended nationwide crises that impact nuclear facilities. These centers could be used by nearby countries to practice international coordination and response scenarios.
- Governments should ensure that plans to protect facilities against natural disasters are not solely focused on safety equities, but also consider security incidents.
- As is already the case in many situations, operators should be obligated to conduct risk analyses of various environmental hazards and create response plans for different scenarios. This should be well coordinated with local and regional emergency response planners.
- To address the risk of theft of weapons-usable nuclear materials during crisis scenarios, Governments should commit to supporting and pursuing only nuclear energy technologies that avoid the use of HEU and separated plutonium.
- Governments of countries with stockpiles of civilian HEU and plutonium should commit to eliminating these materials.
  - Where applicable, governments should commit to reducing and consolidating stockpiles as intermediary steps.
  - Such commitments could be codified in IAEA plutonium management guidelines, Information Circular 549.[34]

[33] Lessons Learned from the Fukushima Nuclear Accident for Improving Safety of U.S. Nuclear Plants, (National Academies of Sciences, Engineering, and Medicine, National Academies Press eBooks, 2014), https://doi.org/10.17226/18294.

[34] IAEA, "Communication Received from Certain Member States Concerning Their Policies Regarding the Management of Plutonium," INFCIRC/549 (March 16, 1998), https://www.iaea.org/publications/documents/infcircs/communication-received-certain-member-states-concerning-their-policies-regarding-management-plutonium.

Role of the IAEA

- In responding to future crises, including domestic and international violent conflicts, the IAEA should embrace a more proactive organizational culture, instead of waiting to be called upon. The agency can provide assistance in many ways within its legal mandate, including encouraging political leadership, providing supplies, sharing information, offering technical assistance, and dispatching experts.
  - The IAEA should clarify its legal basis for providing assistance during armed conflicts.
  - None of these actions should detract or divert resources from the present, ongoing crisis at ZNPP.
- The IAEA should provide detailed recommendations to governments and operators for how they can work together to prepare for and respond to national crises.
  - The IAEA already publishes an implementing guide on national nuclear security threat assessment, design basis threats, and representative threat statements. It should build on these resources with guidance for how to accomplish these goals. The IAEA's International Physical Protection Advisory Service peer review missions are a possible means to establish criteria for evaluating preparedness to respond to national crises.
  - The IAEA's Nuclear Security Division should also host an international conference to examine the intersection of nuclear safety and security.

Strengthen Industry-Focused Organizations

- WANO's peer review and analysis of incidents should expand beyond nuclear safety.
  - WANO should develop a process for security peer reviews that includes a module for crisis resilience, with each state committing to invite peer reviews commensurate with the nature and scale of its nuclear activities.
- Industry and industry organizations should create a self-sustaining entity that brings stakeholders together to share information and best practices to strengthen cybersecurity at nuclear facilities.

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About the Nuclear Threat Initiative

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