

McCULLOUGH RESEARCH

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Subject: Russian Federation Actions and Intentions at the Zaporizhzhia Nuclear Power Project (ZNPP)¹

On Friday, March 4, 2022, Russian Federation troops reportedly shelled the largest nuclear power plant in Europe, Zaporizhzhia NPP in Ukraine.² A reactor was hit, as well as spent fuel storage casks, and a fire was ignited at the training center near the reactors. Soon after, Russian troops seized control of the grounds. As this is typed, troops are currently occupying the plant and, in some confusing fashion, supervising the plant's operators.³ Recently, there were reports that communications with the plant -- including radio-activity monitoring -- had been lost.⁴

This is the second nuclear facility Russian forces have occupied. The first, Chernobyl, has been inactive for years, but still remains a serious risk to public safety if daily operations are interrupted. Current reports indicate that Russian forces are also approaching a third nuclear power plant in Ukraine, at Yuzhnoukrainsk.⁵

¹ <https://www.howtopronounce.com/zaporizhzhia> indicates that the correct pronunciation of the plant is "za-por-izhzhia".

² <https://www.npr.org/live-updates/2022/03/07/ukraine-russia-nuclear-plants-humanitarian>

³ <https://www.theguardian.com/world/2022/mar/06/ukraine-zaporizhzhia-nuclear-plant-staff-under-russian-orders>

⁴ <https://www.reuters.com/world/europe/iaea-loses-touch-with-monitoring-equipment-ukraine-power-plant-2022-03-09/>

⁵ <https://thehill.com/policy/international/europe/596986-russian-forces-closing-in-on-another-nuclear-facility>

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A recent New York Times article speculated on Russian intentions at Zaporizhzhia. While these speculations are relevant, they may not have anticipated the full scale of Russian aspirations in Ukraine or the implications for neighboring members of the North Atlantic Treaty Organization.⁶

While the immediate plans of the Russian army are unclear, the occupation of at-risk nuclear facilities in the course of an “intense crisis” was a scenario in Herman Kahn’s classic on nuclear strategy, *On Escalation*.⁷

RUNG 15. BARELY NUCLEAR WAR: It may occur at any of the previous four rungs, but most particularly between Rungs 11 and 14, that one or a small number of nuclear weapons is used unintentionally as a result of the reduced safeguards and new stresses of an intense crisis. “Unintentional” uses could also be deliberate, in that the user could try to give an impression that a deliberate use was unintentional. There are at least two reasons for such deceptions. First, the mere fact that a nuclear “accident” had occurred would indicate clearly to the opponent, and to others who could put pressure on him, that the situation was very dangerous. The fact that the incident is called unauthorized or accidental gives special point to the warning and reduces the likelihood of retaliation or other escalation. (And such a course of action is a two-edged sword; it can also deter or frighten one's own side. The differential advantages to be achieved or lost by raising such apprehensions depend in part on the details of the balance of military power and the internal discipline and control each side has.) Second, the attacker may feel that it is particularly important to destroy some key enemy installation (for example, a centralized command and control headquarters, a particularly strategic base, a warning center, or the like) and find that he can do so only with nuclear weapons. He might destroy this installation and still hope that the opponent would accept it as an accidental or unauthorized use of a weapon. The offending side could offer to punish the guilty individuals, perhaps to provide an indemnification, or to permit a reprisal (but not really a compensating one) by the other side.^{8,9}

High visibility occupation of successive nuclear facilities like Chernobyl, Zaporizhzhia, and Yuzhnoukrainsk may simply reflect command and control issues or the signal the beginning of an end game strategy to neutralize NATO’s military and economic superiority. In either case, it is important to take precautionary steps to reduce the risk of a nuclear “accident.”

The chart below shows the location of critical nuclear facilities in the Ukraine and neighboring Russia:

⁶ <https://www.nytimes.com/2022/03/04/science/ukraine-nuclear-power-plant.html>

⁷ *On Escalation*, Herman Kahn, Praeger 1965, pages 88 and 89.

⁸ Herman Kahn uses the term “rung” to refer to steps along the path to a nuclear exchange.

⁹ *Ibid.*, pages 88-89. Emphasis supplied.



The Zaporizhzhia Nuclear Power Plant (ZNPP) is located on the bank of the Dnieper River in southeast Ukraine. It is comprised of 6 VVER-1000 nuclear reactors of 1980s soviet vintage, and is touted as the largest nuclear plant in Europe, ninth largest in the world and larger than any in the US. It produces 5,700 MW of nameplate capacity. Varying from thirty to forty years of age, the six units are reaching the end of their economic life.

By U.S. standards, the six units are clustered very closely together which dramatically increases the level of risk.

Curiously, the level of security at the plant appeared to have been quite minimal:

¹⁰ Created using ESRI ArcGIS Online Mapping Software



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ZNPP provides nearly half of the nuclear generation and more than one fifth of the overall electricity used in Ukraine. ZNPP is situated near to the Zaporizhzhia Thermal Power Plant (ZTPP) which produces another 3,650 MW from 7 coal fired units.¹⁴

ZNPP currently has two distinct types of spent fuel storage. Active cooling ponds, which require electricity to keep nuclear waste from overheating, and long-term dry-storage casks. Undisturbed dry storage casks are relatively safe without intervention. However,

¹¹ Google Street View – Front gate, Promyslova St

¹² Google Street View – South equipment gate, Unmarked road

¹³ Google Street View – North gate near Dry Storage – Unmarked road

¹⁴ https://www.worddisk.com/wiki/Zaporizhzhia_thermal_power_station/

active cooling ponds can be extremely dangerous. Much of the risk at the Fukushima nuclear power accident came from the necessity to maintain active cooling for used fuel rods.¹⁵

Press coverage on Wednesday, March 9, 2022, indicates that the power and communications have been shut off at Chernobyl.¹⁶ While this has no immediate connection to ZNPP, it raises a concern about the cooling of spent fuel at the facility. Chernobyl still has an existing cooling pond and evidence exists that water in the pond must be pumped from the nearby Pripyat River.¹⁷ The IAEA has indicated that there would not be a critical impact on the safety of the facility, but it is unclear on which mitigating factors that assessment depends.¹⁸

In the past few years, Ukraine has been shifting nuclear related contracts from Russia to Western companies and nations.¹⁹ Traditionally, spent fuel from the cooling ponds would have been sent via railroad in dry-casks to Russia for recycling. But recently, used fuel has instead been stored on-site.²⁰ The image below depicts the active cooling waste storage ponds in green and the open-air yard where the dry storage casks are kept in orange.

¹⁵ <https://www.science.org/content/article/near-miss-fukushima-warning-us-panel-says#:~:text=At%20Fukushima%2C%20the%20earthquake%20and,decay%20gradually%20heated%20the%20water>

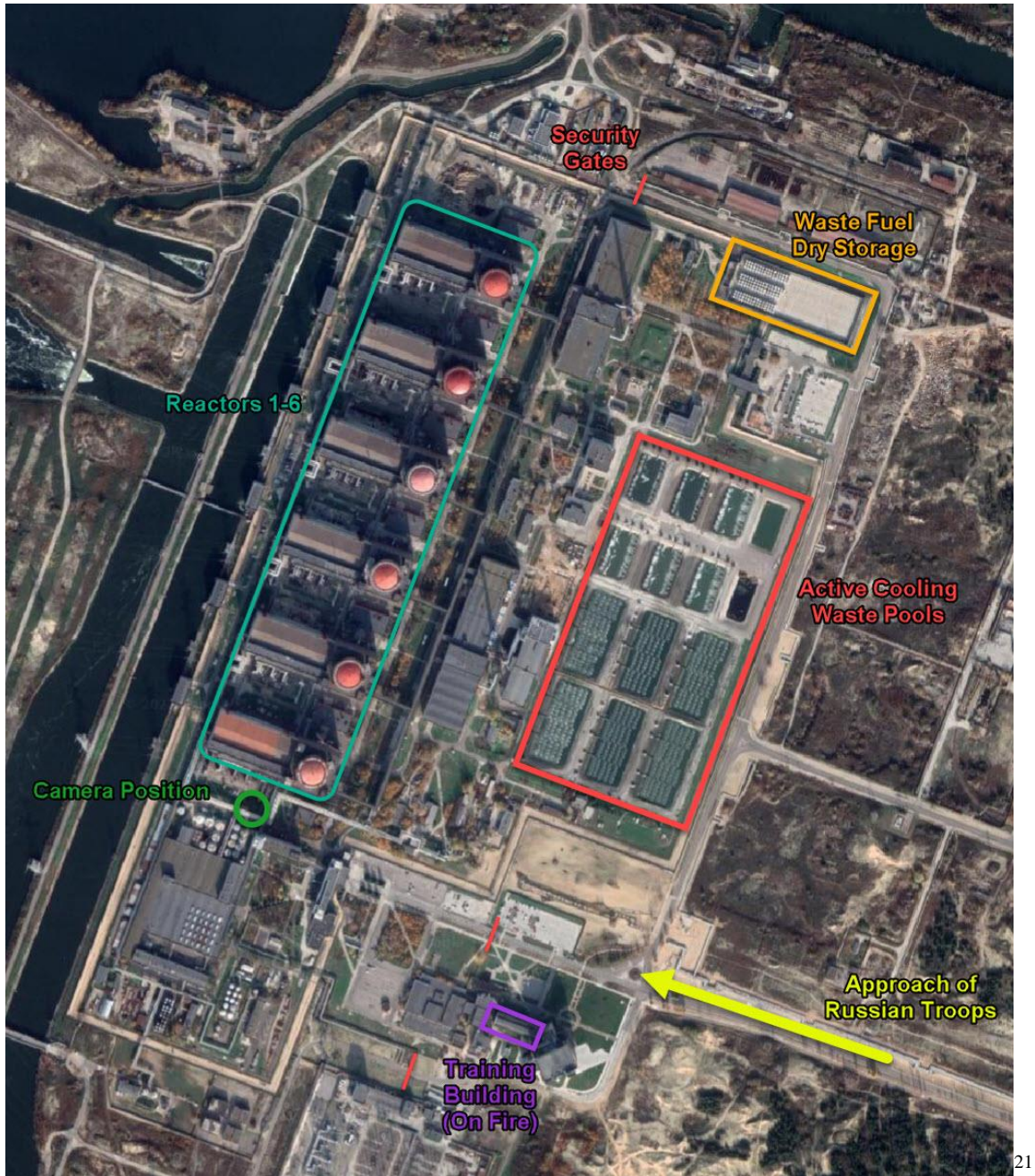
¹⁶ <https://www.reuters.com/world/ukraine-nuclear-firm-warns-radiation-risk-after-power-cut-occupied-chernobyl-2022-03-09/>

¹⁷ The cooling pond of the Chernobyl nuclear power plant: A groundwater remediation case history. Dmitri A. Bugai et al, April 1997, page 2.

¹⁸ https://twitter.com/iaeaorg/status/1501665264903016457?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Etweet

¹⁹ <https://www.neimagazine.com/news/newswestinghouse-signs-contract-with-ukraine-for-first-ap1000-9277721#:~:text=Westinghouse%20Electric%20Company%20and%20Ukrainian,reactors%20to%20the%20Khmelnitskyi%20NPP>

²⁰ <https://www.power-technology.com/projects/zaporizhzhya-nuclear-power-plant/>



Reports of the Russian attack on ZNPP have varied. The New York Times has reported that a shell has hit one of the six reactors.²² Actual video coverage of the fire fight is

²¹ Generated using Google Maps

²² <https://www.nytimes.com/2022/03/04/science/ukraine-nuclear-power-plant.html>

available at Overdefense.com.²³ The image above also shows the angle the Russian army approached, the position of the camera, the location of the training center fire, and the security checkpoints.



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From the video coverage, it would appear that the actual fire fight occurred to the south of the reactors with Ukrainian defenders sheltering in the training center. Obviously, much of the coverage is very preliminary. It can be noted, however, that firing northwest towards the reactors could reflect command and control problems with the Russian military, or it could be a clear message to the international community of the fragility of ZNPP and other Ukrainian nuclear facilities.

A major impact on the containment vessel by a missile or an artillery shell could be catastrophic. In 2009, Duke staff at Crystal River conducted an orderly engineering project to expand the access to the containment vessel in order to perform needed maintenance.²⁵ In the course of the construction, the containment vessel “delaminated” – an unusual term that can be roughly translated to “destroyed”. Crystal River was closed permanently as a result of the mishap.²⁶

The key engineering takeaway is that containment vessels are designed to contain the nuclear materials inside the vessel. They are imposing but fragile when threatened from outside. It should be clear to anyone that reactors are not to be shot with artillery fire.

There is substantial evidence that the Russian army was taken unaware by Putin's decision to launch a full invasion. Reports of desertions, fuel and food shortages, and the relatively slow rate of advance all speak to a lack of training and effective leadership. It is

²³ <https://www.overtdefense.com/2022/03/03/zaporizhzhia-pitched-battle-at-europes-largest-nuclear-power-plant/>

²⁴ Google Maps Street View – Russian tank’s view approaching ZNPP

²⁵ <https://www.power-eng.com/nuclear/reactors/evaluating-an-unexpected-crack-in-containment/#gref>

²⁶ https://www.world-nuclear-news.org/C_Duke_gives_up_on_Crystal_River_0502131.html

possible that a local commander was unaware of the possible outcome if his fire penetrated the containment vessel of an operating nuclear plant.

The ZNPP is not on the route to a more important objective. Its location on an unbridged section of the Dnieper actually made it a detour for troops needed elsewhere.

While it seems possible that Russian Federation troops are being diverted to occupy industrial facilities and then opening fire on the facilities that they were tasked to preserve, the sheer scale of the facility from ground zero might make any local commander consider what target he was engaging.



Most important, however, involves Russia's intentions concerning the nuclear facilities they are occupying. Occupying Chernobyl was particularly mysterious. Chernobyl has

²⁷ Google Maps Image - https://www.google.com/maps/place/Zaporizhzhya+NPP/@47.5066894,34.585138,3a,77.8y,90t/data=!3m8!1e2!3m6!1sAF1QipP6k5_TRnth-Ov7iHlaGxn_3XmYhbUbQ1eb5TgU!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipP6k5_TRnth-Ov7iHlaGxn_3XmYhbUbQ1eb5TgU%3Dw203-h152-k-no!7i1024!8i768!4m5!3m4!1s0x40dcbebe768d89bf:0xa333933b4be25625!8m2!3d47.5070945!4d34.5852935

no operating significance other than the risk it exposes to neighboring areas. The existing management of the plant was competently handling that risk.

The press has reported a number of different hypotheses concerning Russia's intentions for the attack. Some are highly troubling.

1. Purposeful creation of nuclear risk or the perception of nuclear risk

At ZNPP, press reports indicate that the operators are being supervised in some fashion by Russian soldiers. As anyone with a background in nuclear generation will attest, this is a very odd statement. Nuclear plant operations are challenging at the best of times. Operating older soviet era plants even more so. An additional level of untrained "supervision" makes them even more dangerous – not less so.

In addition, the reported interruption of normal communications from the plant, including readouts from radiation monitoring devices, raises doubts about the integrity of the unit after the impact of a shell or a missile during the initial fire fight.

2. Interruption of Electricity to Ukrainian citizens

As a matter of physics, the alternating current grid is not directed from a specific plant. A reduction of electricity at ZNPP might – and usually does – have effects across a large area with results that are difficult to predict from the control area of a power station. This is why dispatch decisions are made at dispatch centers which do have the ability to adjust flows to specific areas.

The objective to reduce electric service in unoccupied Ukraine is far easier and vastly safer to accomplish by simply knocking down the transmission links to Kharkov and Kiev. Any good command and control tactic would of course capture critical infrastructure, like bridges and power plants, but actually shutting off power to lands you expect to quickly occupy is not terribly advantageous.

3. Preserving the asset from Ukrainian sabotage

This is even less plausible. Sabotaging a nuclear plant in defense of your home is self-defeating. Historically speaking, in 1941, the Red Army did destroy the nearby Dnieper hydroelectric dam to keep it from the hands of Nazi invaders, and to remove one of the only potential river crossings. However, this dam breach caused a flash flood, killing between 20,000-100,000 people downriver, and did not stop the Germans from occupying the region for over 2 years. Remembering these losses, it certainly would not be in the Ukrainians' best interest to purposefully initiate a nuclear disaster, particularly in lands they expect to keep.

4. Access to nuclear waste

One hypothesis was for Russia to gain access to the stored nuclear waste to use as fuel for nuclear weapons. This, however is very unlikely, since Russia has access to far more efficient weapons that wouldn't leave a cloud of radiation over their own nation.

5. Overt terrorism and/or nuclear blackmail

While the direct use of nuclear weapons in Ukraine might well spark international intervention, the failure of a Ukrainian nuclear plant would be “deniable” by the occupying troops and laid at the feet of the Ukrainian government, rather than the Russian occupiers. Similarly, any claims of “missing” fuel, and a subsequent public release of nuclear waste could easily be blamed on Ukrainian insurgents.

The fifth hypothesis has implications for NATO and other neighboring countries. Occupation of nuclear facilities may well represent a strategy of threatening nuclear accidents on the defender's soil if occupied by enemy forces.

There are international bodies tasked with taking control and establishing safety protocols, goals of which the Russian Federation is a party. The International Atomic Energy Agency should be encouraged to attend to this exceptionally dangerous situation by sending personnel to Ukraine, to observe and, if necessary, step in to assure that the facilities are being safely maintained.

Section 5 of the Statute of the International Atomic Energy Agency directs that the agency's role is:

5. To establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy;²⁸

It should be noted that Herman Khan's scenario does not stop at the borders of Ukraine. Lightly guarded facilities in eastern European NATO member countries like Slovakia, Hungary, Romania, and Bulgaria could also play a role in an unintentional nuclear accident.

²⁸ <https://www.iaea.org/about/statute>

Even the nuclear facilities in neutral countries like Finland and Sweden could serve, although the political implications of such a step makes it less likely.



Overall, the fact remains that the Russian Federation is expending scarce resources to secure facilities with very limited military value. If the fire fight at Zaporizhzhia was not a mistake, it might signal a very dangerous move in a game of nuclear escalation.

²⁹ Created using ESRI ArcGIS Online Mapping Software