



## **A Knife in a Nuke Fight: The Weaponization of Nuclear Reactors in War**

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### **JCSP 50**

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## **A KNIFE IN A NUKE FIGHT: THE WEAPONIZATION OF NUCLEAR REACTORS IN WAR**

### **INTRODUCTION**

The unexpected Russian seizure of the Zaporizhzhia Nuclear Power Plant (ZNPP) in Ukraine has altered the conduct of war into the future.<sup>1</sup> The seizure, and subsequent failed attempts by Ukraine to re-take the ZNPP, are novel evolutions in war and demonstrate that states in future armed conflict will likely view nuclear power infrastructure, like all other critical infrastructure, as a target.<sup>2</sup> In such a conflict, these high-value energy systems would logically then become a critical asset one would desire to control, or potentially deny the use of to an adversary.<sup>3</sup> The primary case study in this paper will be that of the ZNPP seizure. The central argument of this paper is that given the above evolution, it is necessary that Western militaries adapt to this new paradigm, to include actions to mitigate and potentially preempt accidental, collateral, or intentional creation of a nuclear incident by adversary action.<sup>4</sup> The impact this will have on the future on warfare, however, has not thoroughly been considered academically.

This paper will support the central argument through examining: (1) Future nuclear power trends globally; (2) Precedent for involvement of nuclear reactors in combat and conflict and the utility of doing so; (3) The legal standing of nuclear reactors as military objectives under international law; (4) Finally, this paper will outline principles and considerations of a framework for the conduct of targeted and deliberate military actions to mitigate risk of nuclear incidents – accidental or otherwise. It is not flippantly that this paper contemplates military actions in and around a nuclear reactor, and these decisions should not be taken without due consideration for collateral and humanitarian consequences.<sup>5</sup>

### **FUTURE NUCLEAR POWER TRENDS GLOBALLY**

#### **Power Generation and Climate Change**

Power generation alone accounts for 40% of energy related emissions of carbon dioxide.<sup>6</sup> As a result, the world is moving to cut reliance on forms of power generation

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<sup>1</sup> Brumfiel et al., “Russian Attack on Zaporizhzhia Nuclear Plant More Dangerous than First Thought.”

<sup>2</sup> Orlova, “Ukraine Commandos Tried to Liberate Zaporizhzhia Nuclear Plant 3 Times.”

<sup>3</sup> Amnesty International, “Russian Attacks Causing Catastrophic Damage to Critical Energy Infrastructure in Ukraine.”

<sup>4</sup> This paper presupposes the imperative to respect international humanitarian law as it relates to the consideration of effects on the civilian population. It assumes that the Canadian government, and broadly Western governments, will be intent on upholding the Rules Based International System. Particularly with respect to the ICRC, and Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977.

<sup>5</sup> Not the least of which is under article 56 of Additional Protocol 1 to the Geneva Conventions.

<sup>6</sup> World Nuclear Association, “Carbon Dioxide Emissions From Electricity.”

that emit Green House Gasses (GHGs).<sup>7</sup> The primary contender for reducing the carbonization of power generation is nuclear power.<sup>8,9</sup> Initiatives being undertaken by advanced nations to include nuclear power expansion to developing nations.<sup>10</sup> Combined with the progress in developing new types of nuclear power reactors and the growing commercialization of the nuclear power market, the barrier to accessing the benefits of peaceful nuclear power are being lowered.<sup>11</sup> This means that more nuclear reactors will likely be present in more parts of the world, and in some cases this will include countries with a limited history of stability, significant regional security challenges, and a lack of experience with safely and securely operating and regulating nuclear infrastructure.<sup>12</sup> The logical deduction from this line of reasoning is that it is likely that nuclear reactors will become a more common feature of the future battlespace.

Under the construct of the Paris Agreement of 2015, and as of 2023, country-level targets for Net Zero GHG emissions now represent 89% of the global population, 92% of global GDP, 88% of global GHG emissions; meaning that the majority of the world population - and economic power - resides within jurisdictions which have agreed to Net Zero emissions goals.<sup>13</sup> As public sentiment shifts towards support for nuclear power for environmental reasons, governments are looking to leverage this for both GHG emissions goals, while supporting economic prosperity.<sup>14,15,16</sup> By 2050, the International Atomic Energy Agency (IAEA) projects that global electrical energy production will rise from 82.3 ExaJoules (EJ), to 159.6 EJ - nearly doubling - at the same time that the world seeks to meet its obligations to reduce emissions.<sup>17</sup> This necessitates phasing out relatively lower cost carbon-intensive forms of power generation in favor of non-emitting forms capable of handling the continuous base load power demand.<sup>18</sup> Enter the Nuclear Power Reactor (NPR), and its role in a Nuclear Power Plant (NPP).

### **Traditional Nuclear Power Reactors**

Traditional NPRs used in NPPs are large and complex systems which have the proven ability to continuously generate large amounts of power, with little pollution, from a relatively small amount of fuel.<sup>19</sup> While the exact design and operation of a NPP is beyond scope of this paper and varies with the reactor type and model, the concept is straightforward if technically involved. In sum, NPPs use the heat from controlled

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<sup>7</sup> International Energy Agency, "The Energy World Is Set to Change Significantly by 2030, Based on Today's Policy Settings Alone."

<sup>8</sup> World Nuclear Association, "Carbon Dioxide Emissions From Electricity."

<sup>9</sup> Grossi, "5 Reasons Nuclear Energy Is Key to the Climate Transition."

<sup>10</sup> Banks and Massy, "Nuclear Power in Developing Countries? Let's Talk about It."

<sup>11</sup> Abdulla and Morgan, "Nuclear Power for the Developing World."

<sup>12</sup> Abdulla and Morgan.

<sup>13</sup> NewClimate Institute et al., "Net Zero Stocktake 2023," 4.

<sup>14</sup> Kennedy and Kennedy, "Growing Share of Americans Favor More Nuclear Power."

<sup>15</sup> World Nuclear Association, "Nuclear Power in Japan."

<sup>16</sup> World Nuclear Association, "Nuclear Power in Germany."

<sup>17</sup> International Atomic Energy Agency, "Energy, Electricity and Nuclear Power Estimates for the Period up to 2050," 17.

<sup>18</sup> University of Calgary, "Baseload Power - Energy Education."

<sup>19</sup> World Nuclear Association, "Nuclear Power and Energy Security."

nuclear reactions to heat a fluid (generally water), which generates steam and drives steam-turbine-generators to generate electricity.<sup>20,21</sup>

However, owing to the significant up-front capital costs and the need to establish educational, commercial, and regulatory systems to sustain them, NPPs have largely been the purview of advanced, developed nations.<sup>22</sup> Additionally as a result of the Chernobyl, Fukushima, and other nuclear incidents, there are significant pockets of public opposition to expansion of nuclear power projects around the world. While this public perception is changing, there remain obstacles to overcome.<sup>23,24</sup>

Despite this, and owing to their characteristics, NPPs still have significant potential to play a large role in addressing the immediate need to generate base load power.<sup>25</sup> Multiple nations are now reversing their nuclear bans or restarting dormant reactors while the world transitions away from fossil fuels.<sup>26,27</sup> High-range assessments by the IAEA estimate an effective doubling of nuclear power generating capacity by 2050 despite retirements of older NPPs.<sup>28</sup>

As of March 2024, approximately 10% of the world's electricity is generated by 439 traditional NPRs installed at NPPs around the world.<sup>29</sup> The generating capacity for a traditional NPR is typically over 300 Megawatts of Electrical power (MWe), but can be greater than 1000 MWe.<sup>30,31,32,33</sup> In the face of both high capital cost, latent public opposition, and a need to rapidly deploy electrical power generation free from GHG emissions at scale, a new concept has emerged: The Small Modular Reactor (SMR).<sup>34</sup>

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<sup>20</sup> “What Is the Clean Energy Transition and How Does Nuclear Power Fit In?”

<sup>21</sup> Rather than producing GHG emissions during operation, NPPs produce a mixture of radioactive waste products, which are safely contained at the NPP, cooled in pools of water, and stored in protective containers on site. In the coming years, waste will increasingly be held in long-term sub-terranean repositories away from large human populations, while its radioactivity decreases over time.

<sup>22</sup> Banks and Massy, “Nuclear Power in Developing Countries? Let’s Talk about It.”

<sup>23</sup> Kennedy and Kennedy, “Growing Share of Americans Favor More Nuclear Power.”

<sup>24</sup> This paper will use the Ukrainian spelling of Chernobyl, as opposed to the Russian spelling Chernobyl.

<sup>25</sup> “What Is the Clean Energy Transition and How Does Nuclear Power Fit In?”

<sup>26</sup> World Nuclear Association, “Nuclear Power in Germany.”

<sup>27</sup> World Nuclear Association, “Nuclear Power in Japan.”

<sup>28</sup> International Atomic Energy Agency, “Energy, Electricity and Nuclear Power Estimates for the Period up to 2050.”

<sup>29</sup> World Nuclear Association, “Nuclear Power Today.”

<sup>30</sup> International Atomic Energy Agency, “What Are Small Modular Reactors (SMRs)?”

<sup>31</sup> US Office of Nuclear Energy, “Nuclear Power Is the Most Reliable Energy Source and It’s Not Even Close.”

<sup>32</sup> Currently, traditional NPRs are constructed on site, along with their containment facilities, and the larger NPP complex – often collocated with other similar reactors to maximize economies of scale.

<sup>33</sup> Gupta, “Exploring the Largest Nuclear Power Plants in the World.”

<sup>34</sup> International Atomic Energy Agency, “What Are Small Modular Reactors (SMRs)?”

## Small Modular Reactors

SMRs are smaller NPRs that are fabricated in a central location and transported to their installation site.<sup>35</sup> Multiple units can theoretically be linked together to produce higher amounts of electricity to meet demand, similar to traditional NPRs in a NPP.<sup>36</sup> Currently, in Canada multiple companies have obtained licenses for the installation of test SMRs at existing Canadian NPPs or nuclear research facilities.<sup>37,38,39</sup>

From the perspective of risk, as these reactors are inherently designed to produce less power, they contain less nuclear fuel and therefore generate less heat that must be managed in a crisis.<sup>40</sup> When coupled with the quality control benefits of mass production, both the probability of failure and the severity of the failure are likely reduced – theoretically reducing overall risk, this however remains to be seen in practice.<sup>41</sup> While the near future will likely see the continued operation of larger NPRs within NPP complexes, a major component of the future growth of nuclear capacity is expected to be led by SMRs.<sup>42</sup>

## Micro Modular Reactors

A further subset of the SMR, alternatively called the very Small Modular Reactor (vSMR), the Micro Modular Reactor (MMR), or Microreactor has emerged.<sup>43</sup> Exact technical and regulatory constraints are still being developed, but they would typically generate 10MWe to 30MWe or less.<sup>44,45</sup> MMRs, conversely to SMRs, have effectively existed for decades in the form of military nuclear reactors at the hearts of nuclear powered vessels such as aircraft carriers, submarines, cruisers, and even frigates.<sup>46,47</sup> MMRs are now operational for civilian purposes in China, India, and Russia, and are being tested as power sources for remote communities.<sup>48</sup> Based on recent analysis by Ontario Power Generation, Canadian Nuclear Laboratories, and Mirarco, MMRs

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<sup>35</sup> It is however acknowledged that the first SMRs, will likely be built on site, as is the case in Canada, while the designs and requirements are tested and validated.

<sup>36</sup> International Atomic Energy Agency, “What Are Small Modular Reactors (SMRs)?”

<sup>37</sup> Canadian Nuclear Laboratories, “Siting Canada’s First SMR.”

<sup>38</sup> Nuclear Engineering International, “Companies Team up to Build Canada’s First SMR.”

<sup>39</sup> The attractiveness of the SMR for power generation has many factors, but the primary concern from the perspective of this paper is the reduced risk of a nuclear incident.

<sup>40</sup> SMR designs often incorporate passive safety systems, which make it difficult for the reactor to enter adverse operating conditions.

<sup>41</sup> Government of Canada, “Small but Mighty: Unveiling the Power of Small Modular Reactors.”

<sup>42</sup> International Energy Agency, “Nuclear Power and Secure Energy Transitions – Analysis.”

<sup>43</sup> Caron et al., “Small Modular Reactor (SMR) Economic Feasibility and Cost-Benefit Study for Remote Mining in the Canadian North: A Case Study,” 1.

<sup>44</sup> Caron et al., 1.

<sup>45</sup> National Research Council and Defence Research and Development Canada, “Emerging Technology Snapshot: Small Modular Reactors.”

<sup>46</sup> Conca, “How The U.S. Navy Remains The Masters Of Modular Nuclear Reactors.”

<sup>47</sup> Wikipedia, “Nuclear Navy.”

<sup>48</sup> World Nuclear Association, “Small Nuclear Power Reactors.”

represent an opportunity to significantly lower cost and improve carbon emissions in remote mining operations.<sup>49</sup>

From a military perspective, Defence Research and Development Canada (DRDC) identifies SMRs, and particularly MMRs, as having potential military applications for remote installations.<sup>50</sup> The United States Department of Defense (USDoD) – outside of the already nuclearized US Navy - is actively pursuing the use of MMRs to power its facilities, with one of the first being Eielson Air Force Base in Alaska.<sup>51,52,53</sup>

Coupled with the above discussed projection to double nuclear generating capacity globally, and the smaller capacity of SMRs and MMRs by design, it will logically follow that the actual number of active nuclear reactors globally will most likely increase.<sup>54</sup> In sum, the world will generate more electricity from many more, much smaller, nuclear reactors than in the past. This means that in the future, nuclear reactors will be present in more varied designs, sizes, locations, and applications than ever before – from military bases, to mining camps, to industrial facilities.

## **PRECEDENT FOR NUCLEAR REACTORS IN CONFLICT**

### **Nuclear Reactors and Modern Warfare**

Nuclear reactors, whether for power generation or not, have been involved in war as soon as they were invented.<sup>55</sup> On operations nuclear reactors are present wherever nuclear-powered vessels are employed – beginning with the USS Nautilus in 1954.<sup>56</sup> However, there are fewer instances of large static facilities being involved in combat as the targets of kinetic strikes and objectives in combat, and only in relatively recent history.

Of these instances, there have been three since 2007 that were either operational or nearly so: (1) The Israeli strike on the Syrian al-Kibar plutonium production reactor,

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<sup>49</sup> Caron et al., “Small Modular Reactor (SMR) Economic Feasibility and Cost-Benefit Study for Remote Mining in the Canadian North: A Case Study,” vii.

<sup>50</sup> National Research Council and Defence Research and Development Canada, “Emerging Technology Snapshot: Small Modular Reactors.”

<sup>51</sup> United States Air Force, “Micro-Reactor Pilot Program Reaches Major Milestone.”

<sup>52</sup> Additionally, active projects are underway with BWX Technologies to design transportable MMRs which could be used to power forward operating bases.

<sup>53</sup> US Department of Defense, “DOD Exercises Option on Second Micro Nuclear Reactor Design.”

<sup>54</sup> Based on the average generating capacity of each active reactor decreasing in line with SMR & MMR design envelopes, while the total bulk generating capacity increases. This would logically infer that the number of reactors would have to increase overall.

<sup>55</sup> Lerner, “The First Nuclear Reactor, Explained.”

<sup>56</sup> Wikipedia, “USS Nautilus (SSN-571).”

(2) the unsuccessful Hamas attack on the Israeli Dimona reactor in 2014, and (3) the Russian attack and seizure of the ZNPP in March of 2022.<sup>57,58,59</sup>

The case of the ZNPP is unique and will be explored further. It is the first instance of an operating NPP being seized by a military force, then held and fortified against counter-attack.<sup>60</sup> The success of the operation set off a flurry of activity within the international community, drew condemnations from Western nations, and prompted rebuke and condemnation from the International Atomic Energy Agency (IAEA).<sup>61,62,63</sup> Despite recent kinetic strikes of unacknowledged origin at ZNPP, the situation remains apparently stable.<sup>64</sup> These conditions belie significant concern among Western nations about Russian control of ZNPP.

### **Why the West Should Be Concerned**

Russia, and the Soviet Union before it, has had a problematic history of (1) civilian nuclear safety;<sup>65</sup> (2) transparency around nuclear incidents;<sup>66</sup> (3) poor consideration of downstream environmental hazards;<sup>67</sup> (4) the targeting and destruction of civilian energy infrastructure;<sup>68</sup> (5) and the targeting and destruction of infrastructure protected under the Geneva Conventions, Additional Protocol I (API).<sup>69</sup> Given these past issues, a reasonable fear would be a large-scale release of radiological contamination from a nuclear incident - intentional or not.<sup>70,71</sup> One can argue that this is purely alarmism, and that the inherent design safety, actions of dedicated NPP operators (such as placing reactors into 'cold shut down'), would significantly reduce the risk of a nuclear incident through active and passive safety systems.<sup>72</sup> These rebuttals however ignore a critical concept in NPR engineering: Design Basis Threat (DBT).

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<sup>57</sup> Garwood-Gowers, "Israel's Airstrike on Syria's Al-Kibar Facility: A Test Case for the Doctrine of Pre-Emptive Self-Defence?"

<sup>58</sup> Carlson, "Prohibition of Military Attacks on Nuclear Facilities," 1.

<sup>59</sup> Zurita, "The Zaporizhzhia Nuclear Power Plant Taken as Military Target: Legal and Technical Global Challenges."

<sup>60</sup> Nelson and Norteman, "What to Do about the Zaporizhzhia Nuclear Power Plant."

<sup>61</sup> International Atomic Energy Agency, "Director General Grossi Alarmed by Shelling at Ukraine NPP, Says IAEA Mission Vital for Nuclear Safety and Security."

<sup>62</sup> "War in Ukraine."

<sup>63</sup> Nonetheless, as of the writing of this paper Russian forces remain in control of ZNPP. ROSATOM personnel are operating the plant, and all of the reactors are in cold shutdown. There have been no reported nuclear incidents at the plant. IAEA inspectors now have access, if supervised, and telemetry from remote monitoring systems now flows to the IAEA.

<sup>64</sup> International Atomic Energy Agency, "Update 224."

<sup>65</sup> Wikipedia, "Effects of the Chernobyl Disaster."

<sup>66</sup> Wikipedia, "Nyonoksa Radiation Accident."

<sup>67</sup> Wikipedia, "Kyshtym Disaster."

<sup>68</sup> Amnesty International, "Russian Attacks Causing Catastrophic Damage to Critical Energy Infrastructure in Ukraine."

<sup>69</sup> ICRC, Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977., art. 1.

<sup>70</sup> Diaz-Maurin, "The Largest Danger at the Zaporizhzhia Nuclear Power Plant."

<sup>71</sup> Dolzikova and Watling, "Securing Zaporizhzhia with Diplomacy and Deterrence."

<sup>72</sup> International Atomic Energy Agency, "Update 224."

The DBT, in a US and Canadian context, sets regulatory standards for the design of nuclear reactors to address a range of non-natural threats.<sup>73,74</sup> Interestingly, military assaults are omitted, as the implicit assumption in civilian nuclear power regulation is that it is the military's role to mitigate the threat of military assault.<sup>75</sup> This has been explicitly contemplated and affirmed by US regulatory authorities. At this time, it is logical to conclude that no civilian NPP is capable of withstanding military kinetic strikes while guaranteeing that there will not be a nuclear incident. Therefore, any combat involving more than small arms, in and around a NPP inherently exceeds its DBT, and creates a real risk of nuclear incident, regardless of safety systems present.<sup>76</sup>

The closest analogue to the possible worst-case scenario for a nuclear incident in the case of the ZNPP would be the Chernobyl Disaster of 1986, which caused local destruction and contaminated a large area.<sup>77</sup> In terms of the ZNPP while it was operating outside of Cold Shutdown, modeling from the Centre for Nuclear Security Science and Policy Initiatives at Texas A&M University suggests that such a release would have not only contaminated the immediate area around the ZNPP, but would have potentially affected multiple nations while allowing Russia to possibly escape the effects.<sup>78,79</sup> Of far more concern however is the risk of an intentional nuclear incident caused by one of the parties of the conflict that is timed to achieve maximum effect.<sup>80</sup> The question remains as to the rationale behind intentionally causing a nuclear incident where the party causing the incident may be affected.

### **The Insanity of Weaponizing a Nuclear Reactor**

On the surface, the premise of a state actor – in this case Russia - intentionally causing a nuclear incident would be insane. To consider causing a nuclear incident on the scale of Chernobyl would be utterly without reason and logically invite consequences on a huge scale. The consequences of such a release can be far-reaching, long lasting, and in many cases, unpredictable.<sup>81</sup> The extent of dispersion of radiological material largely depends on weather patterns and the nature of the incident. The effects would vary over a large area and change with time. Moreover, the territory most heavily affected could be that which Russia has claimed as its own and illegally annexed.<sup>82</sup> If radiological material were to harm NATO member countries, or citizens, there could potentially be reaction

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<sup>73</sup> It includes terrorist attacks with small arms, and since review post 11 September 2001, contemplates aircraft impacts.

<sup>74</sup> Nuclear Regulatory Commission, Nuclear Regulatory Commission: Design Basis Threat, 12705.

<sup>75</sup> Nuclear Regulatory Commission, 12710.

<sup>76</sup> International Atomic Energy Agency, “Director General Grossi Alarmed by Shelling at Ukraine NPP, Says IAEA Mission Vital for Nuclear Safety and Security.”

<sup>77</sup> United Nations, “CHERNOBYL: THE TRUE SCALE OF THE ACCIDENT.”

<sup>78</sup> Ragusa, “NSSPI Researcher Evaluates Impact of Large Release of Radioactive Materials from Ukrainian Nuclear Power Plant.”

<sup>79</sup> Depending on time of year and meteorological conditions

<sup>80</sup> Diaz-Maurin, “The Largest Danger at the Zaporizhzhia Nuclear Power Plant.”

<sup>81</sup> United Nations, “CHERNOBYL: THE TRUE SCALE OF THE ACCIDENT.”

<sup>82</sup> Ragusa, “NSSPI Researcher Evaluates Impact of Large Release of Radioactive Materials from Ukrainian Nuclear Power Plant.”

from the Alliance.<sup>83,84</sup> If clearly attributed to Russian activity, the international reaction could be anticipated to be severe. Finally, the reputational and economic damage incurred by Russia due to an attributable intentional nuclear incident could also be severe. In sum, the argument is that Russia has little to gain and much to lose - or do they?

### **The Precedents and Consequences**

However, the actual consequences for Russia may not be as severe a deterrent as it may seem, and there is precedent in the Soviet experience with the Chernobyl disaster, as well as the recent allegedly Russian destruction of protected infrastructure at the Kakhovka dam.<sup>85</sup>

First, consider the consequences. The closest proxy for such an event is the Chernobyl disaster of 1986. This event occurred due to operator error, insufficient safety protocols, and poor reactor design.<sup>86</sup> The result was an explosion and the complete destruction of one of Chernobyl's NPRs. This led to the creation of local radiological conditions where lethal doses of radiation were experienced within moments. It caused the local dissemination of radioactive components and material, and radioactive fallout regionally and globally.<sup>87</sup> In 2005, the UN concluded that the death of approximately 50 individuals had been directly attributed to the Chernobyl disaster, while in the subsequent 20 years a total of up to 4000 people could die as a result.<sup>88</sup> Later studies reported by the Union of Concerned Scientists, and critical of the UN report, place the worldwide number of fatalities – primarily due to cancers – between 12,000 and 57,000 with 95% confidence.<sup>89</sup> However, for comparison, within the first six months of the Russian full scale invasion of Ukraine the US National Institute of health has reported that 5,552 civilians were killed outright and a further 24,382 were killed in mass atrocities.<sup>90</sup> These figures do not include the deaths of combatants on either side, which currently number in the hundreds of thousands. When considering the food security impacts of such an incident, it can be compared again to the Chernobyl disaster where, as of 2021, radiological contamination of Ukrainian crops persists, meaning that large amounts of Ukrainian agricultural output cannot be used for human consumption.<sup>91,92</sup> Consistent with Russian military practice, contamination of large areas productive agricultural land may in fact be a desired outcome of a "scorched earth policy".<sup>93,94</sup>

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<sup>83</sup> Harman, "What Will NATO Do If Radiation from Zaporizhzhia Reaches Its Members?"

<sup>84</sup> Graham, A resolution responding to the threat posed by the Russian Federation's deployment of tactical nuclear weapons, and for other purposes., 3.

<sup>85</sup> Glanz et al., "Why the Evidence Suggests Russia Blew Up the Kakhovka Dam."

<sup>86</sup> World Nuclear Association, "Chernobyl Disaster."

<sup>87</sup> World Nuclear Association.

<sup>88</sup> United Nations, "CHERNOBYL: THE TRUE SCALE OF THE ACCIDENT."

<sup>89</sup> Union of Concerned Scientists, "How Many Cancers Did Chernobyl Really Cause?"

<sup>90</sup> Haque et al., "The Human Toll and Humanitarian Crisis of the Russia-Ukraine War."

<sup>91</sup> Harvard Kenneth C. Griffin Graduate School, "Radioactive Contamination Still Detected in Chernobyl Crops."

<sup>92</sup> University of Exeter, "Crops near Chernobyl Still Contaminated."

<sup>93</sup> Bigg, "Russia Adopts 'Scorched Earth' Tactics in Bakhmut, a Ukrainian Commander Says."

<sup>94</sup> Schwartz and Welsh, "Russia's Food War."

Second, consider the precedent for violation of international law in the destruction of the Kakhovka dam, downstream on the Dnipro River from the ZNPP. On the June 6, 2023, Russian forces allegedly conducted a clandestine operation on the Kakhovka dam. The result was the inundation of large downstream areas, untold destruction of property, contamination of land with agricultural and industrial pollutants.<sup>95</sup>

Finally, consider the international reaction to a potential nuclear incident. The economic, diplomatic, and reputational damage from an intentional nuclear incident at the ZNPP would be catastrophic for Russia were it not for the fact that Russia is already subject to significant political and economic isolation that has failed to dissuade them from their current course of action. Moreover, it is not certain that an attack could successfully be attributed to Russia, as it would paradoxically require Russian participation in the investigation, made more difficult by their control of access to the ZNPP.

Given the number of civilian deaths due to atrocities, the casualties already incurred in fighting in Ukraine, and a historic disregard for civilian consequences, a potential significant loss of Russian or Ukrainian civilian life would not deter the Russian government from its war aims. The argument can also be made that the Russian Government may have little to lose at this point and potentially gain a military advantage.

### **Perhaps More Pragmatic Than Insane**

In terms of benefits to Russian aims, maintaining the status quo of control over the ZNPP allows them to threaten – even implicitly – a nuclear incident.<sup>96</sup> If they were to cause an incident, the attendant effects could deny large parts of Ukraine to be used by the Ukrainian people or military, like the results of the Chernobyl Disaster. In a military context, this could serve to create a barrier for advancing forces, or a sort of “no-man’s-land” between both sides – similar to the effects of destroying a dam and flooding a large downstream area.<sup>97</sup> A radiological release further contaminating food crops may greatly affect Ukraine’s economic output as approximately 8% of their GDP is derived from agriculture.<sup>98</sup> This would likely compound existing effects from the Chernobyl disaster. Finally, if a large-scale incident was to take place contaminating a wide area, it may force the evacuation of multiple regions, in multiple countries, creating civil panic and a humanitarian crisis on the borders of, and within, bordering NATO countries.<sup>99,100</sup>

As shown in preceding sections of this paper, the presence of nuclear reactors in military operations is nothing new. Moreover, there exists historical precedent for the targeting of Nuclear Reactors for kinetic strikes – whether operational or not. Finally, Russia has demonstrated that the seizure of a NPP as a military objective – for whatever

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<sup>95</sup> Glanz et al., “Why the Evidence Suggests Russia Blew Up the Kakhovka Dam.”

<sup>96</sup> Diaz-Maurin, “The Largest Danger at the Zaporizhzhia Nuclear Power Plant.”

<sup>97</sup> Dolzikova and Watling, “Securing Zaporizhzhia with Diplomacy and Deterrence.”

<sup>98</sup> World Bank National Accounts, “Agriculture, Forestry, and Fishing, Value Added (% of GDP).”

<sup>99</sup> Ragusa, “NSSPI Researcher Evaluates Impact of Large Release of Radioactive Materials from Ukrainian Nuclear Power Plant.”

<sup>100</sup> Dolzikova, “Degradation Everywhere.”

ultimate ends – is feasible. Not only is it feasible, but from a military operational and strategic perspective - potentially desirable depending on war aims. Russia has also demonstrated a willingness to violate International Humanitarian Law in the pursuit of their aims. Irrespective of historical precedent or recent Russian actions, the legal implications of targeting nuclear reactors are particularly relevant if Western forces wish to counter this trend.

## LEGAL STANDING OF NUCLEAR REACTORS IN CONFLICT

As discussed above, current trends show that nuclearization of power generation – for civilian and military purposes – is increasing. If nuclearization is increasing globally, logically the probability of encountering a nuclear reactor in a theatre of operations will increase as well, not only in developing nations, but including in formerly stable regions such as Eastern Europe and the Indo-Pacific.<sup>101,102,103</sup> To that end it is necessary to understand the legal standing of nuclear reactors in war.

On the legal standing of NPP's context matters. From an international humanitarian law perspective, the concern is rightfully about the impacts on civilians. Article 56 of the Additional Protocol I to the Geneva Conventions of 12 August 1949 – referred to subsequently as the 'API' - specifically contemplates the protections of NPPs; or in the language of the document, “nuclear electrical generating stations” and affords them protections in line with dams and dykes. Specifically, paragraph 1 states:

Works or installations containing dangerous forces, namely *dams, dykes* and *nuclear electrical generating stations*, shall not be made the object of attack, even where these objects are military objectives, if such attack may cause the release of dangerous forces and consequent severe losses among the civilian population. Other military objectives located at or in the vicinity of these works or installations shall not be made the object of attack if such attack may cause the release of dangerous forces from the works or installations and consequent severe losses among the civilian population.<sup>104</sup>

It establishes protections for NPP and incorporates the requirements of military necessity and proportionality when it adds the qualifier “if such attack may cause the release of dangerous forces and consequent severe losses among civilian population.”<sup>105</sup> The result of this is that a NPP may be a target if the strike can meet both of those criteria, although the party conducting the strike would conceivably bear the burden of consequences if wrong, as shown in paragraph 2153 of the ICRC commentary.<sup>106</sup>

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<sup>101</sup> World Nuclear Association, “Emerging Nuclear Energy Countries.”

<sup>102</sup> International Atomic Energy Agency, “Energy, Electricity and Nuclear Power Estimates for the Period up to 2050,” 106.

<sup>103</sup> International Atomic Energy Agency, 62.

<sup>104</sup> ICRC, Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977.

<sup>105</sup> ICRC.

<sup>106</sup> ICRC.

Subsequently, paragraph 2 outlines the cases in which the protections in paragraph 1 will cease. In the case of a NPP:

2. The special protection against attack provided by paragraph 1 shall cease:

(a) ...

(b) for a nuclear electrical generating station only if it provides electric power in regular, significant and direct support of military operations and if such attack is the only feasible way to terminate such support;

(c) for other military objectives located at or in the vicinity of these works or installations only if they are used in regular, significant and direct support of military operations and if such attack is the only feasible way to terminate such support.<sup>107</sup>

This would indicate that nuclear electrical generating stations, whether a traditional NPP, SMR, or MMR, would be legitimate military targets if they are directly supporting military operations, or other significant military objectives are collocated, and only way to remove that support is to target and strike the NPP.

### **Proving the Target is Valid**

However, it must also be acknowledged that it would be difficult to demonstrate that there were no other feasible ways to achieve the termination of support – therefore the legal protection would stand. This is a valid argument, and from a Western perspective would likely be upheld. However, the test of whether Western militaries should adapt to this emerging threat is not whether *the West* would take unilateral military action against a NPR, but whether their *adversaries* would. From the perspective of adversaries who explicitly reject the Western-backed Rules Based International System, the restraint that Western militaries show is itself something which can be exploited for military advantage. In the case where an adversary intends to cause a nuclear incident, effectively weaponizing the NPP, legal protections for the NPP could be lost.<sup>108</sup> The crux of proving that protections have been lost however, is intelligence and evidence of sufficient veracity to justify military actions, before and after the fact. In all cases, the party conducting the actions must work to protect the civilian population from the negative effects such that:

3. ... the civilian population and individual civilians shall remain entitled to all the protection accorded them by international law, including the protection of the precautionary measures provided for in Article 57 . If the protection ceases and any of the works, installations or military objectives mentioned in paragraph 1 is

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<sup>107</sup> ICRC.

<sup>108</sup> This could arguably cause the loss of special status under para 2.(c) of the API above, and legally enable military strikes – whether kinetic or not – on the grounds that the NPP itself is now itself a military weapons system.

attacked, all practical precautions shall be taken to avoid the release of the dangerous forces.<sup>109</sup>

None of these conditions or precautions are novel. All military actions must be considered against their potential for civilian collateral damage. It stands to reason that the targeting and striking of facilities with the potential to cause significant collateral damage and harm to civilians would be restricted. It also stands to reason that there would be exemptions to these protections. Particularly notable gaps exist in these protections such as research reactors, medical isotope production reactors, or reactors producing nuclear material for nuclear weapons, although in all cases the requirement to consider civilian collateral damage would remain intact.<sup>110,111</sup>

### **Application to Zaporizhzhia**

In examining the Russian seizure of the ZNPP and applying the API above, there are likely legal issues with the Russian military's selection of the ZNPP as a target in the first place - despite the way in which it was seized having yielded minimal collateral damage thus far. In the case of the ZNPP, it maintained a protected status under the API as outlined above. It was not providing the necessary "regular, significant, and direct support to military operations" which would have caused it to lose its protections.<sup>112</sup> Moreover, the seizure of the NPP did not necessarily meet the requirement of Military Necessity as it is unclear what legitimate military advantage was gained, even if the principles of Distinction and Proportionality appear to have been respected.<sup>113,114</sup> Upon further examination, there is potential gap under the Geneva Convention in relation to re-taking a seized NPP. It raises the question of whether the original owner of the NPP has the legal authority to re-take the NPP from the occupying force. Not explicitly contemplated in the API, this situation is particularly relevant to Ukraine. If Russia is using the facility for military purposes beyond its local defence, the ZNPP may have lost some of the legal protections.<sup>115</sup>

It must be pointed out that these principles and legal protections, however noble and well intentioned, are predicated on a rules-based system where parties have an interest in following the rules. There will likely be cases in which state actors disregard the rules in the pursuit of military or national objectives. This is evidenced by the previously discussed destruction of the Kakhovka dam, the systematic destruction of

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<sup>109</sup> ICRC, Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977.

<sup>110</sup> Zeith and Giorgou, "Dangerous Forces: The Protection of Nuclear Power Plants in Armed Conflict."

<sup>111</sup> Carlson, "Prohibition of Military Attacks on Nuclear Facilities."

<sup>112</sup> ICRC, Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977.

<sup>113</sup> Carlson, "Prohibition of Military Attacks on Nuclear Facilities."

<sup>114</sup> Brumfiel et al., "Russian Attack on Zaporizhzhia Nuclear Plant More Dangerous than First Thought."

<sup>115</sup> The argument being that the ZNPP may now be a legitimate military objective for Ukraine, in that its absence is depriving their civilian population and industry from a significant portion of their electrical power. In either case, the attacking party must make certain that they will meet the requirements for the protection of civilians from consequences of re-taking the facility, and that the principles of distinction, proportionality, and neutrality are respected.

Ukrainian energy infrastructure, and mass atrocities committed by Russian forces against civilians. Furthermore, suppose imminent adversary actions are known with high certainty through intelligence or evidence, where the intended or unintended consequences are very likely to have significant destructive and long-term negative effects. In that case, it becomes arguably necessary for other responsible state actors to take action to prevent those outcomes.

## **DEVELOPING A FRAMEWORK TO ADDRESS THE THREAT**

### **“Who Needs a Knife in a Nuke Fight Anyway?”<sup>116</sup>**

It must be stated up front that the nuclearization of power generation is a net positive as assessed by the IEA and IAEA. The development of SMRs and MMRs for civilian use alone will enable significant reductions in emissions for remote installations, resource extraction operations, and artificial intelligence systems. However, the expanding and rapid deployment of nuclear power globally requires that states and their militaries adapt to the increased prevalence of NPRs conflict. There are foreseeable cases in which military action by a responsible state actor, targeting a nuclear reactor or facility, is the lesser of evils. This is founded on the following premises extracted from the discussion and argument above.

First, if we accept that nuclear reactors will become more common, they will also become more commonly involved in conflict. Second, if we accept the first premise, it behooves responsible states to be able to react, anticipate, adapt, and mitigate the risk of accidental and collateral damage because of conflict.<sup>117</sup> Third, suppose we accept that an adversary, as discussed in the case of Russia above, may wish to attack a nuclear reactor and seize it as a military objective (as has proven the case with the ZNPP). In that case, responsible states need to be prepared to mitigate the risks of an incident as a result of accident, incompetence, or possibly intent.<sup>118,119</sup> It can then be argued that unless opposed, the seizure of the ZNPP will not remain an isolated occurrence and that it will happen again.<sup>120</sup> Finally, suppose we accept that a nuclear reactor can become a

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<sup>116</sup> Verhoeven, Paul. 1997. *Starship Troopers*. United States: Sony Pictures Releasing.

<sup>117</sup> The purposes of these mitigations would be the preservation of human life and the minimization of civilian collateral damage in accordance with the principles of International Humanitarian Law. To do this, states will need to have plans to secure their nuclear infrastructure from military attack. In fact, this is explicitly contemplated and permitted under the API discussed above.

<sup>118</sup> For purposes malign or not, and potentially in contravention of international law and convention.

<sup>119</sup> Diaz-Maurin, “The Largest Danger at the Zaporizhzhia Nuclear Power Plant.”

<sup>120</sup> Based on the forecasted expansion of nuclear power generation, the frequency with which reactors will be present in the battlespace will increase, covered in the first section of this paper.

legitimate target. When faced with an adversary who is likely to cause a nuclear incident, responsible states should intervene.<sup>121,122</sup>

**“All You Gotta do is Push a Button!”<sup>123</sup>**

The detailed technical characteristics and procedures involved are beyond scope of this paper, and best left to experts working within the civilian and defense nuclear engineering and science fields, and with the militaries of responsible states. However, there are likely significant differences in which forms of intervention are possible based on the type of reactor and facility; from traditional NPP to MMRs which will be explored below.<sup>124</sup> In defining and bounding the solution space proposed, the IAEA’s seven pillars are informative and provide guidance, but are designed for continued operation of a nuclear power plant within safety guidelines.<sup>125</sup> In a military context there may be aspects which may need to be adapted depending on the tactical and operational situation on the ground.<sup>126</sup> The main principles which should be used in the development of military options are:

First and foremost maintain reactor(s) physical integrity including, cooling, control system, and backup power supply.<sup>127,128</sup> Second, reduce reactor activity. This should be preferably done by using the existing control systems, following existing reactor operation protocols, by the trained engineers and technicians familiar with operating that reactor.<sup>129</sup> Third, provide site security. In addition to military security, a safe working environment must be ensured for the engineers and technicians to monitor the reactor.<sup>130</sup> Site security needs to be defensive in nature and compliant with the spirit

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<sup>121</sup> These actions may include diplomatic and economic pressure alone, such as public attribution of adversary intent and sanctions tied to adversary actions; however, in the context of a belligerent actor who is willing to violate international laws and norms, military force may be required. Military interventions could include the conduct of activities from posturing, demonstrations, and targeted strikes (kinetic or not) to reduce either the probability or severity of an incident, with the intent of reducing overall civilian collateral damage.

<sup>122</sup> Under article 56 of the API, and understanding that the spirit of the API is the protection of civilians from negative collateral consequences of military action

<sup>123</sup> Verhoeven, Paul. 1997. *Starship Troopers*. United States: Sony Pictures Releasing.

<sup>124</sup> Conversely, adversarial states such as Russia – having successfully sized an operating NPP – have likely already developed principles for the planning of such operations. We should logically anticipate such actions against allied NPRs in conflict zones of the future

<sup>125</sup> International Atomic Energy Agency, “IAEA Director General Grossi’s Initiative to Travel to Ukraine.”

<sup>126</sup> Additionally, while these pillars are informative for a traditional NPP, the way in which they apply may change as SMRs and MMRs become more prevalent given that the nature of the reactor drastically affects the risk as will be discussed subsequently.

<sup>127</sup> As evidenced by the Fukushima incident, anything that damages or destroys these systems poses the risk of uncontrolled consequences. If reactor integrity is not maintained, it defeats the purpose of a risk reduction activity or operation.

<sup>128</sup> World Nuclear Association, “Fukushima Daiichi Accident.”

<sup>129</sup> In extremis, reducing reactor activity by activating emergency shutdown systems, or “SCRAMing” the reactor, can be contemplated but there are potentially second order effects on the civilian power infrastructure from a sudden shutdown of generating capacity.

<sup>130</sup> The nuance is that it takes time for a reactor to transition to a complete cold shutdown state, and would therefore logically require provision of security until that occurred. Otherwise, any kinetic strike on the

of article 56 of the API.<sup>131</sup> Fourth, restore open access to international regulatory personnel from the IAEA, transmission of monitoring and telemetry from sensing equipment, and handover to responsible civilian operators and oversight.<sup>132</sup>

The four principles above, while not exhaustive, are derived from both the IAEAs own publications, the analysis of Russian seizure of the ZNPP, and subsequent international pressure that has resulted. They are however only principles, and as discussed subsequently, will need to be applied practically.

### **“Put Your Hand on That Wall!”<sup>133</sup>**

When analyzed with respect to emerging developments in nuclear power generation, the principles outlined above result in a series of critical factors that should be assessed if a military intervention is required that targets a nuclear reactor.

The power output of a nuclear reactor is proportional to the size of the reactor core and hence the amount of nuclear material in it.<sup>134</sup> It is therefore correlated to the amount of nuclear material that could be released in a nuclear incident, and so the maximum severity of a nuclear incident. The power output also translates into the amount of cooling required to maintain the core at a safe temperature. In the case of traditional NPRs this may be significant, however in the case of SMRs and MMRs, it may be significantly less.<sup>135</sup> Therefore the severity of consequences for a nuclear incident may be lower with SMRs and MMRs, which may lower risk overall.<sup>136</sup>

Traditional NPPs are large facilities, with (a) large central reactor(s) and associated control, maintenance, storage, and support facilities. In the case of the ZNPP, waste thermal heat is even provided for district heating in nearby towns.<sup>137</sup> When considering smaller SMRs and MMRs, these reactors may require significantly less support infrastructure and, due to limited thermal and electrical output, be designed to accomplish a core function. Conversely, the applications for which they will be employed will likely be more varied, and may be coupled with petro-chemical operations, steel mills, data centres, mines, and military installations.<sup>138,139</sup> This means that in theory, SMRs and MMRs may individually present a simpler problem, but on the whole present

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reactor itself could still quickly lead to an incident as the physical integrity (principle 1 above) would be violated.

<sup>131</sup> It should include defensive systems appropriate for the threat faced. The defensive forces need to be focused only on defense of the reactor or power plant and cannot be dual use in compliance with the API.

<sup>132</sup> There may be a requirement for responsible nations to establish exclusion zones under UN or internationally recognized agreement and enforce their integrity, a form of ‘nuclear peacekeeping’ for lack of a better word.

<sup>133</sup> Verhoeven, Paul. 1997. *Starship Troopers*. United States: Sony Pictures Releasing.

<sup>134</sup> World Nuclear Association, “How Does a Nuclear Reactor Work?”

<sup>135</sup> Government of Canada, “Small but Mighty: Unveiling the Power of Small Modular Reactors.”

<sup>136</sup> National Research Council and Defence Research and Development Canada, “Emerging Technology Snapshot: Small Modular Reactors.”

<sup>137</sup> International Atomic Energy Agency, “Update 189.”

<sup>138</sup> National Research Council and Defence Research and Development Canada, “Emerging Technology Snapshot: Small Modular Reactors,” 1.

<sup>139</sup> Judge, “Finally - a Nuclear Powered Data Center?”

a broad problem-set where second-order effects on civilian industry may be larger than the first order effects of military action.

Traditional commercial NPPs were generally one of a limited set of reactor types which, owing to their specific characteristics, were commercially viable at the time they were built.<sup>140</sup> The designers of SMRs and MMRs are exploring multiple novel and less common designs, which may yield certain benefits for intended applications. Therefore, the mechanisms of operation will vary, as will safety protocols, and the training and skills required to operate them. This means that finding appropriate expertise to operate and maintain specific reactors may become more challenging. While the principles and considerations are relatively straight-forward, the question remains of what can be done to address the threat in the future.

### **“The Enemy Cannot Push a Button, if You Disable His Hand”<sup>141</sup>**

Currently in Canada, DRDC and the science and technical intelligence establishments are almost certainly under-resourced to support the development of military options to mitigate the threat of nuclear incidents in conflict zones, owing to this being an emerging threat space.<sup>142</sup> Moreover, there is a lack of military controlled nuclear power research facilities within Canada to enable practical solution design and the training of personnel.<sup>143,144</sup> As a leading nation in the development of civilian nuclear power globally, and one of the few countries to develop indigenous nuclear technology, Canada is certainly well positioned to contribute to this effort amongst its allies – but it must first recognize and understand the threat.

The decision to take military actions in vicinity of, or on, a nuclear reactor must be weighed against the military necessity and civilian collateral damage as described in the API. The goal of any military actions taken on a NPR should be to reduce the civilian collateral damage from a nuclear incident caused by an adversary due to accident, incompetence or intent.<sup>145</sup> Owing to the wide variability in outcomes based on the power output, design complexity, and reactor technology a single type of solution is not applicable or desirable. In the case of MMRs and smaller SMRs, the consequences resulting from a munition-based kinetic strike may be small and, a munition-based kinetic

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<sup>140</sup> World Nuclear Association, “How Does a Nuclear Reactor Work?”

<sup>141</sup> Verhoeven, Paul. 1997. *Starship Troopers*. United States: Sony Pictures Releasing.

<sup>142</sup> There is currently a dearth of academic literature about military interventions on operational nuclear reactors. The relatively new space that MMRs and SMRs occupy further compounds these gaps. It therefore stands to reason that this has not been incorporated into resource allocations while maintaining extant mandates.

<sup>143</sup> The exception being the Royal Military College SLOWPOKE reactor, however this is not a suitable site for experimentation and training of military forces. An ideal outcome would be a test and training reactor complex for military purposes, located at CFB Suffield in the Experimental Proving Grounds. The remote location, significant standoff, and inherent expertise at DRDC Suffield would provide ideal conditions for capability development and training. This would also serve as a potential training / proving facility for remote mining / resource extraction operations supported by MMRs for civilian use.

<sup>144</sup> Wikipedia, “SLOWPOKE Reactor.”

<sup>145</sup> These principles apply not only to contemplation of actions against an adversary controlled NPR, but also in the decisions involved in employing our own - anticipating adversary action against them as well.

strike may be sufficient to prevent a larger release by an adversary or enable effective denial. In the case of a traditional NPR or larger SMRs the consequences of a munition-based strike may be catastrophic and be self-defeating.

In that worst case scenario requiring a military action on a traditional NPP or larger SMR, a high level of precision and flexibility would conceivably be required. This would likely place it in the realm of surgical strikes by highly specialized Special Operations Forces, enabled by Space and Cyber capabilities, and supported by forces of conventional military domains.<sup>146,147</sup> Canada may be well positioned to support these kinds of operations, owing to highly proficient, and technically adept Special Operations Forces. Despite the targeting of operating NPRs emerging as a trend in conflict, there are initiatives that can be undertaken now to begin addressing the challenges that lie ahead.

## CONCLUSION

Nuclearization of power generation is increasingly viable and attractive for countries adapting to climate change. The near future will see the proliferation of nuclear reactors of varying designs and capacities around the world, and an increase in the presence of nuclear power reactors. As this happens, so will the presence of nuclear reactors in conflict zones, and presumably the incidences of nuclear reactors as military objectives. This has been most recently, and novelly, demonstrated by Russia in Ukraine at the ZNPP. This new reality of military actions by *irresponsible* aggressor states directed against nuclear infrastructure presents challenges. It is therefore prudent *responsible* states adapt to this reality.

Given this, it behooves responsible states to develop the capabilities to conduct military actions to mitigate the risk of nuclear incidents in conflict zones. This may mean that deliberate targeting of NPRs will be required to mitigate the probability and severity of consequences of nuclear incidents in conflict zones. This must all respect the spirit of Article 56 of the Additional Protocol I to the Geneva Conventions to reduce harm to the civilian population.

With improved resourcing of its defence research and development and defence scientific and technological intelligence establishments, and its world-class Special Operations Forces, Canada can position itself as a value-added ally and global leader in this threat-space into the future.

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<sup>146</sup> From a firepower perspective, these strikes should be as closely bound to the reactor DBT as possible, to minimize the risk of an incident due to an errant munition.

<sup>147</sup> This paper fully acknowledges that there are potential military actions involving non-traditional domains such as CYBER which may be able to achieve desired effects in the absence of physical forces. However, as specific capabilities are likely classified, and each reactor based on generation will have different levels of connectivity, it was omitted from this paper. Any kind of action of this nature would be heavily dependent on the level of digitization and connectivity of NPR control systems with some form of network. The logic being that older traditional NPRs within NPPs in some cases pre-date the modern internet. This being said, as more modern reactors (SMRs and MMRs) come online, this will potentially become a much more viable pathway.

**GLOSSARY OF TERMS**

<u>Acronym</u>	<u>Proper Term</u>
API	Additional Protocol I to the Geneva Conventions of 12 August 1949
DBT	Design Basis Threat
EJ	ExaJoules
GDP	Gross Domestic Product
GHGs	Greenhouse Gasses
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
MMR	Micro Modular Reactor (Also called Microreactor)
MWe	Megawatts (electrical)
MWth	Megawatts (thermal)
NPP	Nuclear Power Plant
NPR	Nuclear Power Reactor
SMR	Small Modular Reactor
vSMR	Very Small Modular Reactor

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