FACULTY
OF SOCIAL SCIENCES
Charles University

Peace Research
Center Prague

ASSESSING CHALLENGES AND OPPORTUNITIES IN THE AGE OF ARTIFICIAL INTELLIGENCE: VIEWS OF NON-WESTERN EXPERTS IN THE DEBATE ON NUCLEAR SECURITY

October 2021

Linda Jaeck

EU Non-Proliferation and Disarmament Consortium

Promoting the European network of independent non-proliferation and disarmament think tanks

Disclaimer: *This report has been prepared as part of a research internship (realized between July 2021 and October 2021) at the Peace Research Center Prague, funded by the European Union (EU) Non-Proliferation and Disarmament Consortium as part of a larger EU educational initiative aimed at building capacity in the next generation of scholars and practitioners in non-proliferation policy and programming. The views expressed in this paper are those of the author and do not necessarily reflect those of the Peace Research Center Prague, the EU Non-Proliferation and Disarmament Consortium or other members of the network.*

INTRODUCTION

With terror and peace as defining characteristics, the nuclear age poses several challenges and opportunities in modern society (Lieber & Press, 2020). For a long time, nuclear weapons were inseparably linked to the West and the Great powers. Since the end of the Cold War, a shift of powers began and is still ongoing (Lodgaard, 2010). For the emerging powers of Latin America, Asia, and Africa, the shift presents new international options as they are no longer bounded to integrate into the present liberal world order. As Lodgaard (2010) argues, in the case of China and India, nuclear weapon programs are rooted in national ambitions. There is a strand of exceptionalism in India's desire for a leadership position in world affairs, and nuclear weapons provide the foundation for that projected aim. In China's instance, the shift to a more powerful position intends to become a vital player in international affairs through the use of nuclear weapons. This demonstrates both the importance of nuclear weapons in a changing international order and the urgency for disarmament. With new narratives such as the growing relevance of emerging technologies in the nuclear area, the question of how to deal with nuclear weapons and disarmament, as well as how these technologies may enhance the disarmament process, is more relevant than ever. First steps have been made towards preventing the spread of nuclear weapons and controlling nuclear non-proliferation and disarmament. The multilateral and legally binding landmark Non-Proliferation Treaty on Nuclear Weapons (NPT) entered into force in 1970. It obliges 191 countries, including the five nuclear-weapon states, to the objective of nuclear disarmament for an unlimited duration (UN, 1995). However, no specific deadline has been set for the completion of full nuclear disarmament.

Scholars have begun to analyze the intersection of emerging technologies and nuclear deterrence, as well as the intersection of emerging technologies in nuclear disarmament from a Western perspective (Acton, 2018, 2020; Chyba, 2020; Sechser et al., 2019; Williams, 2020). The work largely emphasizes crisis escalation and risk perception, with less attention paid to emerging technologies in the nuclear disarmament field. By surveying and interviewing experts primarily from the West, Onderco and Zutt (2021) investigated how developing technologies affect nuclear security and disarmament. The present paper is inspired by Onderco and Zutt's (2021) work and aims at contributing to this already existing debate. However, the approach in this article is more exploratory and involves voices from non-Western countries. Similar to Onderco and Zutt (2021), the present paper focuses on the perceived impact of AI on nuclear disarmament and deterrence. It seeks to contribute to a better understanding of AI's impact on nuclear disarmament and deterrence as well as to illustrate the need for more inclusion in the expert debate on this topic. Hence, the research question is the following: what are the impacts of AI on nuclear disarmament according to non-Western experts? By

interviewing this group, the paper seeks to address a critical, inclusive, and realistic reflection of the current expert debate on deterrence and disarmament of nuclear weapons.

In total, 11 experts from nuclear-armed and non-nuclear-weapon states, namely South Asia, the MENA region, China, Japan, Latin America, the US, and Europe were interviewed or surveyed. The results show that AI's impact has two dimensions; on one hand, it can reduce human errors by pointing out failures. On the other hand, AI has to remain a tool with human monitoring as a top priority. Although the majority of experts believed the expert debate is unidirectionally concentrated on the Western hemisphere, the results do not differ significantly from the Western perspective. Foresight, the need for increased dialogue and a shift in the debate towards greater transparency is essential.

The paper is structured as follows. The first section defines key terms such as emerging technologies, artificial intelligence, and autonomy. The scope and techniques utilized in the study are then presented, followed by a summary of the current state of research on AI's lack of confidence, AI and nuclear stability, deterrence, including the potential risk of inadvertent escalation, and nuclear disarmament. It continues with the findings, followed by a brief comparison with Onderco and Zutt's findings (2021). Finally, it summarizes key results and outlines limitations.

CHAPTER 1: BACKGROUND ON AI, MACHINE LEARNING AND AUTONOMY

AI has been a cornerstone of computer science for nearly 60 years, allowing robots to do tasks independently with simple human intelligence input (Anastassov, 2021). Since then, the term 'Artificial Intelligence' has gone through a variety of different interpretations (Topychkanov, 2020). In universal terms, it is a highly convergent "general-purpose technology that does not stand alone but enhances or adds functionality" when integrated into military systems (Verbruggen, 2020, p. 11). In this context, most definitions gather around thinking and acting rationally and thinking and acting humanly (Russel & Norwig, 2010). Despite the increased interest in Artificial Intelligence or computational intelligence in academia, industry, and public institutions, there is no standard definition of what AI involves. In the context of AI's impact on strategic stability and nuclear risk, Saalman (2019) describes AI as a "catch-all term that refers to a wide set of computational techniques that allow computers and robots to solve complex, seemingly abstract problems that had previously yielded only to human cognition" (p. 5). When talking about AI, the present paper refers to this rather human-centered definition of AI.

Autonomy and machine learning are two major AI applications in weapon systems (Roy, 2020). "To be autonomous, a system must have the capability to independently compose and select among different courses of action to accomplish goals based on its knowledge and understanding of the world, itself, and the situation" (Shattuck, 2015, p. 6). The common definition for the term 'autonomy' concerning machines is "the ability of a machine to perform an intended task without human intervention using the interaction of its sensors and computer programming environment" (Boulanin & Verbruggen, 2017, p. vii).

Emerging technologies include a variety of technologies such as information technology, robotics, and AI (Rotolo et. al, 2015). As a subset of AI, Machine learning uses specialized algorithms to model and understand complex structures and relationships among data and datasets. Both, machine learning and autonomy are likely to have a transformative impact in the nuclear realms, precisely in the nuclear deterrence architecture like in early warning systems and ISR (Boulanin et al, 2020). Forms of machine learning, such as deep learning architectures including deep neural networks, have been applied in the nuclear field. They consist of computer vision where they have produced results comparable to and in some cases surpassing human expert performance (Bengio, et al, 2013; Schmidhuber, 2015). Examples show that AI occurs in conjunction with other technologies and therefore seldom stands on its own. In Cyberwarfare, for instance, AI is considered an integrated tool to repel cyberattacks by enabling the automated detection of cyberattacks, and offer assistance for the conduct of cyberwarfare operations (Boulanin et al, 2020).

AI and Autonomous Systems - a crisis of confidence?

The field of nuclear weapons is not particularly known for its inventive progress and ability to alter quickly (Dunn, 2017; Fihn, 2017; Jadoon, 2021). Government and academic experts have missed significant activities in the proliferation of nuclear weapons, leading to a bleak outlook for the future (Potter & Mukhatzhanova, 2008). Combining AI and nuclear weapons may offer governments a leg up on the competition by increasing an actor's incentive to employ nuclear weapons. The employment of AI as a functional add-on tool to remedy existing system flaws is one potential benefit (Spindel, 2020). In the following, the two views on AI – the optimistic and the pessimistic view - are introduced. As a competing enthusiasm evolves around AI, several Western and Great Power states are considering incorporating one or more of these into their national security programs. The United States declared its AI leadership in 2018 (The White House, 2018), whereas China aspires to be a world leader in AI by 2030. (Department of International Cooperation Ministry of Science and Technology China, 2017). This demonstrates the global interest and need to investigate the potentials and limitations of AI in the security sphere, particularly concerning nuclear weapons. The nuclear field will benefit from current breakthroughs in AI and machine learning, notably in strengthening monitoring systems like those employed by the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) (Le Bras, Russel & Vaudya, 2010).

The approach to Trustworthy AI (TAI) suggests that trust builds the foundation of societies. As a result, individuals will only be able to reach AI's full potential if trust in its development, implementation and use can be built (Thiebes, Lins & Sunyaev, 2020). The current

renaissance of AI and its influence on nuclear weapons and doctrines also poses certain risks. Concerning in this regard is not the technology itself but the emergence of the strategic applications that comes with it (Bauer, 2020). One great risk in adopting autonomous systems is the trust gap of humans, or in the case of AI, the automation bias. Therefore, the machine first has to “prove” itself before being utterly acknowledged. Once they are acknowledged, humans tend to trust the machine, even when there is proof that the machine is ineffective (Horowitz, Scharre & Velez-Green, 2019). Additionally, to the concern around automation bias, autonomous systems can pose risks due to their highly interconnected and complex software-based nature (Perrow, 1984). On a technical level, it makes them more vulnerable to hacking and bugs. A software malfunction caused eight F-22 fighter jets to lose navigation and communication while crossing international dateline (Sheppard, 2007) is just one such example. In his work on risk technologies, Perrow (1984) argues that the more complex and tight-coupled a system, the more prone it is to failures. In the case of nuclear weapons,

the consequences can be catastrophic. Software vulnerabilities can also lead to what Lupovici (2021) calls the "dual-use security dilemma", an extension of the traditional security dilemma by so-called dual-use technologies like AI and Cyber. Those technologies append an additional layer of uncertainty, blurring the lines between peaceful and harmful tools, peaking in highly dangerous nuclear postures in the worst case. For example, lethal manually remote-controlled unmanned combat aerial vehicles (UCAVs) were used in counterterrorism operations in Afghanistan and Pakistan under President Barack Obama, causing casualties among civilians (Xiang, 2019). It is hardly conceivable what collateral damage may be caused by deployed autonomous nuclear weapons. Accordingly, this limits the chances for autonomous systems to safely fulfill their purpose.

CHAPTER 2: AI AND NUCLEAR STABILITY

Currently, there appears to be no consensus among experts on the impact of AI on nuclear security. Given that nuclear assaults have been avoided in the recent past, it is tempting to take nuclear stability for granted. Scholars argue that a simple logical reasoning process paired with certain values might have fatal consequences (Akiyama, 2021). As previous studies demonstrate, AI and nuclear stability were primarily assessed from a constructivist perspective by think tanks and independent research organizations (e.g., van Wyk et al. 2011, 2008; Potter & Mukhatzhanova, 2008). Besides, neoliberal institutionalists introduce alternative paradigms by suggesting a more important role in economics. They are far more optimistic about the prospects for developing international institutions to alleviate security dilemmas and achieve long-term collaboration between states (Keohane & Axelrod, 1985). The actual impact of AI on nuclear stability will become apparent only with time. AI may aggravate strains in nuclear stability, but under conditions mitigate those and contribute to achieving nuclear stability (Geist & John, 2018). It would be favorable for nuclear states to overcome their mutual suspicion and instead work towards this aim collectively.

There are several examples of automation in early warning, delivery platforms and vehicles, and nuclear command control (Horowitz, Scharre & Velez-Green, 2019). This leads to an intensely discussed debate; while some forms of automation in early warning and nuclear command and control are considered relatively uncontroversial, others have culminated it a topic of high controversy and have even been involved in near-accidents (Horowitz, Scharre & Velez-Green, 2019). Boulanin (2020) describes four types of possible nuclear force-related application of AI. The first is in nuclear weapons, the second is in enhanced intelligence, surveillance, and reconnaissance (ISR) against enemy nuclear forces. The third is in nuclear command, control, and communications (NC3) and the final is in conventional weapon systems that are relevant to nuclear forces. In this context, von Braun et al. (2021) note that grave problems may occur if humans rely too heavily on AI input. In addition, Geist and John (2018) identify three views on the possible future of AI and nuclear stability. The first view is that AI will not inherently change the status quo. Subscribers to this 'complacent' belief accentuate the technical of AI side rather than the strategic side. The main argument here is that the mere complexity of nuclear war is too challenging for AI to add meaningful functions, therefore AI's impact becomes more or less irrelevant. On the opposite, Geist and John (2018) identify the alarmist perspective which points out the inevitable influence of AI on the vulnerabilities of existing systems. A deep distrust towards nuclear decision-making of algorithms and the controversial ethical debate is the focus of the alarmist view. AI only needs to be perceived as effective to be destabilizing as in the example of the targeting of adversary launchers. Finally, the subversion perspective is based on AI's vulnerability to adversarial actions. They believe that the

impact will be mainly driven by an adversary's ability to alter, mislead, divert, or trick AI. This can be done by replacing data with erroneous samples or false precedent, or by more subtly manipulating inputs after AI is fully trained. Subversionists acquire their knowledge primarily from theoretical considerations and demonstrations, believing that attacks are likely to be effective. This leads to differing conclusions throughout subversionists as AI sometimes falsely shows increased progress. Geist and John conclude that "when an effective AI for tracking and targeting might be destabilizing and lead to proliferation or worse, an adversary may regain trust in the survivability of its second-strike forces if it is confident in its ability to forestall detection using these adversarial methods, thereby reestablishing strategic stability. On the other hand, an actor may believe that it can subvert an AI's ability to identify a preemptive first strike, making such a strike a viable option and therefore destabilizing" (p. 15).

AI on Nuclear Deterrence

Nuclear deterrence is an essential part of the current expert debate. The question if AI will enhance or weaken the nuclear deterrence is widely discussed among scholars. According to Mazarr (2021, p. 15), "deterrence is the practice of discouraging or restraining someone— in world politics, usually a nation-state—from taking unwanted actions, such as an armed attack" implicitly or explicitly. AI might contribute toward reinforcing the rationality of decision-making under (crisis) conditions, easily affected by the emotional human disturbances and fallacious inferences, thereby preventing an accidental launch or inadvertent escalation (Akiyama, 2021). In reverse, judgments about what fits with the "national interest" do not fit AI (Akiyama, 2021). Regarding the impact of AI on nuclear deterrence, several scholars have discussed the topic primarily from two angles - a skeptical and less skeptical. While the less euphoric view argues in favour of implementing AI particularly within command-and-control systems, the less euphoric perspective points out that breakthroughs in technologies undermine nuclear deterrence due to their vulnerability (Lieber and Press, 2017). By implementing AI, countries may increase first-mover advantages or incentivizing other states (Onderco & Zutt, 2021). This raises the incentives to attack, especially for states without a secure second-strike capability (Horowitz, 2019). Consequently, the likelihood of a nuclear conflict increases.

Scholars postulate that whether deterrence is credible depends upon three factors (Jervis, 2014; Mazarr, 2021). First, the adversary's perception of the capability of the deterrent to carrying out the threatened punishment or denial of aims. Second, the adversary's perception of the will or resolve of the deterrent to making good on its threat. Thirdly, whether the deterrent threat is communicated and understood by the adversary is a matter

that previous crises have demonstrated cannot be taken for granted. Existing literature distinguishes between two fundamental approaches of deterrence (Mazarr, 2021). On one hand, deterrence by denial strategies seeks to deter action by making it unable to succeed, potentially peaking in a heavy loss. On the other hand, deterrence by punishment threatens severe penalties such as nuclear escalation if a state gets attacked. In the global context, Wong et al. (2020) identified the following factors as potentially significant in shaping deterrence in the age of AI. The first factor is the structure of the international system. Depending on the scenario of the future international system, such as a US or China-centric unipolar world, a multi-polar state-centric system, a China-USA bipolar system, or a collapse of the state system, implications for the AI integrated deterrence differ significantly. The second factor looks at how well the adversary is understood. The higher the degree of mutual understanding of adversaries, the lower the risk of misunderstandings. However, significant changes in countries causing a lack of insight may raise the risk of misunderstanding. The third factor is the "AI market environment" (p. 27) as an abstraction that includes the global sector levels of analysis. This involves potential future scenarios from a dominant commercial sector in which military AI systems are mainly derived from commercial systems to competitive or divergent strategies. They contain a low interchange of knowledge to collaboration between public and government sectors to research dominated by governments, with a strong focus on military purposes. Consequently, it can be assumed that different structural models of AI integration in military forces which lead to militaries give existing operational units to AI and autonomous systems. Autonomous systems replace several existing forces with the development of distinct communities among militaries. Subsequently, AI capabilities are outsourced as militaries themselves do not possess any AI capability. Finally, contractors are hired instead for specific functions.

A Risk of inadvertent escalation?

When analyzing the impact which AI has on nuclear deterrence, a main area of risk is inadvertent escalation. It is one of the most destabilizing components of nuclear deterrence (Acton, 2020; Chyba, 2020). Inadvertent escalation was highly concerning during the Cold War times when misinterpretation of certain military acts would lead to nuclear preemption (Cimbala, 2002). When looking at the implementation of AI into systems today, scholars primarily see an increased likelihood for inadvertent escalation (Johnson, 2019). A reason for that is the powerful interplay of increased intelligence or speed in a potential conflict. Johnson (2019) argues that first of all, the reason for the new generation of AI to increase the risk of inadvertent escalation is due to the speed of warfare and the co-mingling of nuclear and strategic non-nuclear weapons. Second, AI-enhanced

cyber counterforce capabilities could lead to greater complications in cyber defense. On account of the technical complexity of military systems, it becomes more likely to escalate (Perrow, 1984) which in consequence impacts decision-making, especially when the state is not secure (Schelling, 1966).

AI on Nuclear Disarmament

Any debate on AI in nuclear disarmament deserves a closer examination of the current state of research. Over the past decades, scholars have argued over three main topics in nuclear disarmament, namely nuclear proliferation, nuclear monitoring, and nuclear substitution (Onderco & Zutt, 2021). On one hand, the main factors which discouraged the proliferation of nuclear weapons are reluctance to use nuclear weapons, the high barriers to entry and low incentives for first use once when second-strike capabilities became available, and well-developed verification regimes (Wong et al., 2020). In the case of autonomous systems, however, these factors do not necessarily apply as command and control of nuclear weapons. They are often de-centralized, the barriers are much lower and verification to prevent autonomous systems from proliferating is not viable (ibid). On the other hand, new technologies also create new possibilities in disarmament and non-proliferation. They could improve monitoring by examining if states comply with arms control and improve safeguards (Onderco & Zutt, 2021). Especially the East Asian perspective on disarmament present a critical view towards the application of AI in weapon systems (Il-Soon & Ji-Sun, 2019). Scholars argue that the development of nuclear-powered, unmanned nuclear weapon systems such as unmanned underwater vehicles (UUV's) fundamentally violates the NPT. One possible step towards a nuclear-free world would include taking efforts to reduce risks being caused by AI. This contains no first use policies, close collaborations through dialogue, and increased state's willingness to implement modernized plans (Boulanin, 2018). Finally, nuclear-armed states must take note of the importance of this issue as part of the bilateral and multilateral talks on nuclear risk reduction in order to achieve long-term disarmament.

CHAPTER 3: EXPERT SURVEY AND INTERVIEWS

To measure the impact of AI on nuclear disarmament and deterrence, I approached experts in the field. The main idea was to find similarities and differences in views between regions, precisely between Western and non-Western experts, and differences between non-Western experts from different countries. The analysis was compiled qualitatively, using an exploratory research design, relying on two methods of collecting data. Five interviews with experts, from which three could eventually be used, and eight surveys distributed to experts. The eleven surveys and interviews were conducted between July 25, 2021, and September 3, 2021 (out of 145 experts invited). The majority of the experts interviewed and surveyed responded to the substantive questions in detail while often going beyond answering the initial questions. Very few questions were not answered in the survey. The majority of respondents consisted of either academics based at a university or think-tank researchers. They come from a mix of nuclear weapons states and non-nuclear weapons states. A majority of them works in nuclear policy, disarmament, nuclear risk reduction and negotiations, security policy, strategy, nuclear engineering, conflict, non-proliferation, radicalization, and globalization. To ensure a geographical representation, I consulted experts from South Asia, Latin America, the MENA region, Japan, and China. The experts were chosen based on two major criteria: geographical representation and portfolio (field of research related to the nuclear sphere and AI). One limitation is, however, that two Western experts were included in the final results as well. Their contributions slightly differed from the non-Western opinions but had the same core arguments and aims for future terms. When selecting the experts, the focus was laid on experts from international organizations and think tanks, universities, and authors who published in major international peer-reviewed journals. The survey used was based on the submission developed by Onderco and Zutt (2021). Since they focused more broadly on emerging technologies and the impact on nuclear security, I adjusted the questionnaire with a particular focus on AI. The survey was non-scenario based, contained five primary questions and two sub-questions most of which aimed at evaluating the impact of AI on nuclear dynamics. The expert interviews were the addition to the survey and aimed at receiving detailed insights on the topic. Most experts discussed the questions excessively, considering technical, political, and ethical dimensions of how AI affects the nuclear sphere and how AI can impact nuclear disarmament and deterrence.

Findings and Discussion

In the survey and during the interviews, the focus was set particularly on AI and its role within nuclear disarmament and deterrence because of its relevance in scholarly circles.

1. The impact of AI on inadvertent escalation increases

When looking at the potential of inadvertent escalation, the question whether AI improves or challenges the risk of inadvertent escalation in comparison to smart conventional weapons is primarily concerning. Experts generally agreed that it is likely for inadvertent risks to rise when AI is used in nuclear weapon systems. Notably, it is particularly political and ethical criteria that should be taken into account before implementing AI into nuclear weapons systems.

However, among the experts interviewed and surveyed there was a slight variation depending on the region. While most experts coming from Japan and the MENA region were less skeptical, experts from China and Latin America expressed sincere concerns that AI leads to unpredictable consequences. One interviewee from China stressed that AI could be used by the adversary to manipulate systems by feeding them with misleading information. Consequently, if a country develops serious misunderstandings about the enemy, this could lead to misjudgments of intentions or an overreaction in appliances peaking in the event of inadvertent escalation. At the technical level, especially inaccurate assessments about the presence of enemy forces could lead to misunderstandings. Some experts pointed out that the negative impact of AI is most likely to develop in early warning systems or nuclear decision-making systems as they could introduce new risks. Overall, the way how AI is applied seemed decisive whether it leads to inadvertent escalation or not.

Four experts stated their neutral position on the question simply because it is not yet to predict how effective or ineffective AI systems will be concerning nuclear weapons. This includes what kind of safeguards may be possible. One expert interviewed referred to the two main elements that both speak for the increase of inadvertent escalation and the plurality of effects that lead to this increase. The first was based on Scott Sagan's (2004) theory about the inevitability of failures in very complex interacting machines. The new failure modes created might not be anticipated by humans simply because everything hinges on another. Therefore, the potential for new systems failure rises by simply introducing more complex systems. The second element of the argument included the introduction of new vulnerabilities in terms of the potential for system interference. In particular, there were concerns about the cyber vulnerabilities of nuclear weapons systems and how these systems can be compromised, even if they are "air-gapped" and they are not connected to the internet. By having the potential, complexity, and sophistication of cyber capabilities - especially among nuclear-armed and

nuclear-allied states - concerns about how these systems that are more dependent and integrated with AI can be attacked were introduced. The automation and algorithmizing of control and command parts are increasingly problematic and may lead to inadvertent escalation. Finally, experts who clearly stated that inadvertent escalation increases were mainly worried about the lack of human monitoring.

2. AI has the potential to carry out strategic tasks

The overall results show that half of the experts agreed on AI having the potential to carry out strategic tasks while the other half is concerned. Some experts argued that it depends on what states are willing to delegate to systems. Others were certain that AI is not capable of carrying out a nuclear attack but certainly plays a variety of roles within the entire strategic chain of nuclear operations. One interviewee argued that the broad concept of deterrence encompasses several adjacent concepts, theories, strategies, flaws, and myths. This covers, inter alia, virtual training and games, most of which already employ AI in some countries. On the one hand, it appears that a push has occurred in terms of what states want. This is to not fully rely on automated procedures in nuclear decision-making, but to leave a healthy human element in place. On the other hand, there are fundamental ways in which automated systems can carry out several capabilities, especially in terms of detection or identification of targets that can impact both, first use and second-strike capability. It is simply a matter of what states decide and how they employ the decision afterwards. AI also plays several potential roles in collecting intelligence about other country's activities, including the utility of AI in early warning systems and decision-making systems. At the technical level, AI might be used to detect, identify, and track other country's strategic activities, especially during operations including mobile missile vehicles and strategic nuclear submarines. The example of the Soviet Union's old dead hand system showed that some parts were automated based on a series of sensors to gauge whether a new attack had occurred. There are some indications that the dead hand is still functioning to some degree, according to experts.

Critical voices from Latin America argued that strategic tasks are extremely sensitive and should rest on human responsibility. It is too risky to include AI on the strategic level due to the lack of human control. Instead, it is safer to involve AI in tactical operations as it provides sufficient space for political supervision. Another interviewee agreed by stating that there is a limit to the extent to which AI can and should be used, especially considering situations like Operation Anadyr (1962), NORAD (1979), and Serpukohov-15, in which an automatic attack was only prevented due to targeted human intervention. Not having humans in complete control of the command loop was an erroneous assessment in every respect. But of course, AI systems could have significant

potential to carry out strategic tasks short of nuclear launches, such as calculating risk factors and projections, to help their human decision-makers.

3. AI is unlikely to replace nuclear weapons in carrying out strategic tasks

By looking at the possibility of AI to replace nuclear weapons systems in carrying out strategic tasks, emphasis was placed on AI's potential role as a strategic weapon. The results are unequivocal. Ten out of eleven experts were pessimistic while only one expert argued it is somewhat likely that AI will replace nuclear weapons in carrying out strategic tasks. Many of the experts agreed that AI in itself is not a strategic weapon. A major argument was that the overall strategic value and role in defense architecture greatly differ as AI can only work based on data. AI may enhance a country's nuclear attack capability but without nuclear weapons, there's nothing for AI to conduct. An expert from Japan argued that to replace nuclear weapons in carrying out strategic tasks, AI weapons should be as destructive and reliable as nuclear weapons. It is somewhat unlikely that any nuclear weapon country believes that AI weapons can become this powerful and destructive. That being said, some experts argued that AI won't replace nuclear weapons as they are connected to a complex network of IO's which impose norms on non-nuclear powers or new nuclear players and codes of conduct. From a disarmament perspective, it sparks a conversation in the other direction. Missing human surveillance and the general political concern about nuclear weapon use as well as the taboo that exists around nuclear weapons were concerns some experts expressed. As a result, a heavy disincentive to shift too much of decision-making to non-human elements occurred.

The broader limit to what humans in security or warfighting contexts are willing to delegate to machines could not be verified. Also, the question to what degree the technology is developed enough to wear trust is not clear. There were a number of experts who believed that testing before the employment is the consequence. This most likely comes with all kinds of backlash from both national and international audiences, if any of the information on nuclear testing were made public. Finally, it has not - at least so far - set off an arms race where other nuclear arms states are making deep developments on this kind of automated aspect of whether it's delivery systems or the weapons themselves.

4. Complete nuclear disarmament is unlikely to happen

The fourth question demonstrates that a majority of experts across regions were reluctant to believe that complete nuclear disarmament happens when leaders are confident that technology will allow for its verification. Some experts argued that perfect confidence in verification may help to promote nuclear disarmament, but it may not be sufficient to achieve complete nuclear disarmament. In this light, the two main arguments said that first of all, the greatest obstacle against international nuclear disarmament is not the absence of effective verification technology. Keeping in mind that technology has always outstripped the pace of reductions and disarmament, the primary obstacle is political in nature. If there was sufficient political will to implement nuclear disarmament, then there would be more investment into researching and developing verification technologies. The second argument was that there are ways in which verification for complete nuclear disarmament already exist. This implies the work done by the academic community and the International Partnership for Nuclear Disarmament Verification (IPNDV). In both cases, the question of whether it is possible to verify disarmament without direct access to nuclear weapons themselves or the knowledge of nuclear weapons to prevent further proliferation is important. This seems crucial, especially since the number of nuclear weapons has not gone down significantly within the past 20 years. The slow reduction is not due to lack of knowledge in verification but due to security circumstances and perceived threats. Without the political will and formal treaties or agreements such as IAEA Safeguards, this, unfortunately, is very unlikely to change. To conclude with the words of a surveyed expert, “the legally binding international objective, enshrined in institutions like the NPT, TPNW, and all NWFZs is achieving global, verifiable, enforceable, and irreversible nuclear disarmament. Verification to avoid cheating is key in that regard. This is not only desirable but also possible, as shown by cases like Latin America (especially Brazil and Argentina), Africa, Central Asia. Those cases also show that a mix of international and regional institutions is key for that objective. Current technology is, however, already enough for such verification. What is missing is political will, particularly among nuclear-weapon-states”.

5. AI is likely to impact nuclear disarmament

The fifth question addresses the influence AI has on nuclear disarmament. Although the impact of AI is quite little and often indirect at this moment, most of the experts found it very likely that AI will have an impact in the future. Arguing from a socio-political perspective, AI can support governments and independent researchers to develop a better understanding of how many weapons nuclear weapon states are possessing and how they are deploying these nuclear weapons. Further, AI technology can help the international

community to better grasp the status of nuclear disarmament by contributing to its international debate and issues. A direct effect of AI is possible through enhancing means of inspection and therefore increasing the sources and data. In the process of verifying the dismantlement of nuclear weapons, this may lead to a future disarmament treaty. Overall, the direct influence of AI on nuclear disarmament has not been discussed intensively in the expert debate, according to experts polled.

AI might have an influence on nuclear disarmament by prevent cheating and reducing the uncertainties that come with strategic disarmament. The prerequisite for this to become reality is the achieved political will. According to one expert, the IAEA uses limited AI capabilities to monitor Iran's compliance with IAEA protocols. However, AI systems will not drive nuclear disarmament because decisions regarding possessing or giving up such weapons are not entirely strategic decisions. Any impetus for nuclear disarmament has been and most likely will always be a political decision first and foremost.

6. AI has more impact on nuclear disarmament and deterrence than other emerging technologies

Question six shows that the majority of experts are confident that AI has more impact on nuclear disarmament and deterrence than other emerging technologies. Some experts argued that in general, scholars are still learning about AI's potential future impact on nuclear deterrence and nuclear strategy. Other emerging technologies such as missile defense, conventional procedure, strike weapons, and cyber have received more attention by now. Missile defense and conventional procedure weapons have been long worried by countries such as Russia and China for their potential impact to undermine nuclear deterrence. Given the fact that cyber has been discussed at large in recent years, some countries worry about exploiting the potential of cyber technology to undermine their nuclear command control system. One expert argued that in previous years, the US may have developed cyber capabilities against a North Korean nuclear missile launch system which enhanced the concerns that cyber technologies could be used by the US against the Russian or Chinese nuclear command control system as well.

According to experts, one reason why the academic community has been unconcerned with AI's influence in the context of disarmament and deterrence is due to its ambiguous nature. AI has the potential to undermine nuclear deterrent credibility, but it also has the potential to contribute to more credible deterrence in specific circumstances. Consequently, the incorporation of AI with shoot and scoot systems such as autonomous

delivery of nuclear bombs would be highly destabilizing for nuclear deterrence, even though AI technologies can aid with disarmament owing to their capacity to allow substantial ISR. As a result, generalizing AI's influence and developing a comprehensive picture of AI's net impact in contrast to other emerging technologies is not possible at this point. Some experts pointed out that the already existing and continuing synergy between AI systems and other new high-tech capabilities such as cyber and space capabilities, robotics, and nanotechnology needs to be looked at in conjunction with each other. It would be a trap to think of those technologies in isolation, as they are often intertwined with each other.

7. The current expert debate is biased towards the West

Question 7 looks at the current expert debate on nuclear disarmament and emerging technologies in a global context. It is considered either “Western-centric, hermetic and deterrence-biased” as it focuses on conjuncture and cosmetic aspects of international security, with little attention to the structural factors that “justify” nuclear armaments”. Or it is Great Powers-centric, according to experts polled. Very few experts argued that the expert debate is neither biased towards the West, nor to Great Power states. Because nuclear disarmament is considered a political process more than anything else, non-Western, and more specifically small states voices should play a role in the debate. However, if the major states' nuclear weapons are to be dismantled, the small states must recognize and account for the major states' security interests. It will not work to insist on a "we are all equal" model, according to an expert interviewed.

Experts criticized the dismissal of non-nuclear-weapon-states, notably those from the Global South, as naïve and irrelevant, and the development of linguistic barriers to prevent them from the action. Other experts argued that the reason for the fairly Western-dominated conversation is due to the fact that legally recognized nuclear-weapon states are either the Great Powers or Western countries. In some parts of the world nuclear weapon use is simply less of a concern or a reality, even if the consequences are quite global and even if there are regional stability issues in, for instance, South America and Africa. Further, the fact that the entire Southern hemisphere is under nuclear-weapon-free zones make the immediacy of the issue less concerning for those countries. Another expert mentioned that several developments in cyber and particularly in AI are constrained to a group of around 30 states, predominantly Western and European countries. He further stated the emergence of new technologies increased the number of actors involved, not just in terms of states, but also in terms of the private sector. However, the actual incorporation of those countries into the debate has not taken place yet. A third expert argued that a way to change the missing integration is a regional approach as

countries facing nuclear risk, including those linked to emerging technologies, cannot be detached from regional and sub-regional security issues that exist already. This approach would provide inroads to engagement. Despite the fact that the debate has always been skewed to some extent because of the West's advanced status, some experts argued that the issue is not about the West versus the East. It is more about "those having nuclear technology and those who do not have it". Arguing from a southern Asian perspective, the situation is still that of classical deterrence and the impact of the emerging technologies has not evoked much attention. Also, according to surveyed experts, "some countries perceive that heightened risks enhance the credibility of their deterrence. This, of course, raises the risk of inadvertent escalation but it is not recognized enough."

Finally, the way how the expert debate takes place heavily relies on the level of democracy within a country. When referring to the engine of the current international debate on nuclear disarmament, experts from China argued that it's mainly think tanks and independent experts that are driving the debate. Governments in less open and less democratic countries would not openly address topics related to nuclear disarmament. In this respect, developing comprehensive and substantive knowledge about challenges at the operational level of nuclear weapons and AI is extremely difficult for independent experts or research institutes. This unilateral communication restricts their potential to judge how relevant and accurate the public debate due to a lack of valuable feedback or input from government officials. Consequently, the debate is stuck, posing the largest hurdle to current international research for less democratic countries.

8. A need for dialogue and transparency

The final question elucidates the gaps in the expert debate on how to improve the existing situation. Most experts argued that first and foremost, the discussion on nuclear disarmament needs to be made publicly available. Discussing the impact of evolving technologies on nuclear weapons is tough unless you're conversant with nuclear weapon systems. As a result, participating in the exchange of information and ensuring transparency is difficult for non-nuclear-weapon states. As one expert argued, "freeing academia from the Western liberalization mission will accomplish more benefits in international security and provide alternative narratives to the currently dominating neoliberal narratives by separating international trust from a normative view on politics and policies". Despite improving exchange with policymakers and scholars from non-Western nations, continuing the current discussion by independent experts may help to raise awareness in less

democratic countries where scholars have limited access to the discussion. By keeping the debate alive in more democratic countries, the chances of meaningful debates spreading into the official arena and affecting governments in less open countries may be more likely. According to a Chinese expert, this initiative is difficult and time-consuming, but it is a possible method to create awareness in a country like China.

Discussion and comparison of the results

In this section, the above results (study B) are compared to the results of Onderco and Zutt's (2021) findings, referred to as study A. Since they focused more broadly on emerging technologies and not just on AI, only the questions that resemble each other are compared. Overall, the findings in both A and B are very similar, displaying only one difference regarding emerging technologies and their potential to carry out strategic tasks. The first key similarity is that experts in both studies disagreed on AI's potential to supplant conventional arms in carrying out strategic tasks. However, while in A the most skeptical experts come from the US and Europe. Experts in B come from India, Japan, and Latin America. The second similarity is that in both cases, experts disagreed that complete nuclear disarmament would occur when leaders believe emerging technologies will make nuclear weapons obsolete. This finding implies that the value of nuclear weapons in Western and non-Western countries goes beyond their role as deterrents. Through the work done by the academic community and initiatives, verification for nuclear disarmament already exists. The obstacle to achieve nuclear disarmament is the lack of political will and not the inadequate technical perquisites. The third commonality shows that specialists in A and B are both confident that emerging technologies such as AI will have an increasing impact on inadvertent escalation. In A, experts argued that AI has the least impact on inadvertent escalation in comparison to cyber capabilities and hypersonic missiles.

A difference between A and B is that in A, the experts are more skeptical about emerging technologies carrying out strategic tasks. While supplanting of conventional arms is unlikely in A and B, the potential of AI to carry strategic tasks is considered likely in B by half of the experts. Experts in B argue that strategic tasks are significantly reliant on the state's decision and how it is implemented afterward. It reflects a broader trend in non-Western countries, particularly Japan and India, to delegate greater responsibility to AI systems. In light of these findings, more detailed research on the exact motivation and mechanisms is needed. Questions of interest include why and when non-Western specialists are not as critical as Western experts, where they are from, and what precisely provoked them.

CONCLUSION

This article explores the impact of AI on nuclear deterrence and disarmament as a follow-up to Onderco and Zutt's study (2021). The findings help to better understand the current challenges of AI in the nuclear area from a non-Western perspective. When AI is deployed in nuclear weapon systems, unintended dangers are likely to increase. This is in line with the findings of Onderco and Zutt's article which examines upcoming nuclear technology primarily from a Western perspective. The overall view on AI's impact is twofold; on the one hand, it can reduce human errors in crises situations by pointing out failures. On the other hand, human surveillance over intelligent software systems is essential to retain control. AI should particularly be approached with caution when considering the interplay between cyber-, conventional, and mixed warfare. When it comes to the interplay of cyber, conventional, and mixed combat, AI should be addressed with caution. It is particularly political and ethical criteria that need to be taken into account before implementing AI into nuclear weapons systems. The second finding suggests that half of the experts agree that AI has the potential to carry out strategic tasks while the other is concerned. This is the only finding which does not correspond directly to Onderco and Zutt's (2021) findings. While some experts criticized the lack of human monitoring that comes with that, others consider the significant potential of AI as a helpful tool (in calculating risk factors for instance). The third main finding shows clearly that AI should not replace nuclear weapons in carrying out strategic tasks. Missing human surveillance and the general political concern about nuclear weapon use as well as the taboo that exists around nuclear weapons are major concerns. As a result, there is a heavy disincentive to shift too much of decision-making to non-human elements. The finding that nuclear disarmament will not take place until world leaders are certain that the technology allows for its verification shows that the role of nuclear weapons goes beyond their role as deterrents. This explains the barely existent reduction in nuclear arms since the end of the cold war. It further shows that the reduction is due to a lack of political will, formal treaties, and fines, rather than a lack of technological innovation. Despite the fact that AI's impact is currently minor and primarily indirect, the majority of experts believe AI will have an impact in the future. In comparison to other emerging technologies such as cyber capabilities and hypersonic weapons, it is thought to be the most promising. Overall, Western and non-Western expert opinions correspond heavily as both sides seek for responsible handling of AI in nuclear weapons and on the other hand agree that AI enables great features as an additional tool. It may be inferred that the ongoing lack of inclusion of non-Western experts is not due to a discrepancy in opinions or aims but rather based on structural issues which makes it difficult for non-Western to engage in the current expert debate.

LIMITATIONS

Although the expert's selection criteria include their origin, it cannot be ruled out that some experts argue from a 'Western' point of view. Further, due to limited participants, the study includes two experts' voices from Western countries. In addition, some experts have received their education or worked on nuclear-related matters in the West. As a result, a bias towards the West cannot be excluded.

BIBLIOGRAPHY

Acton, J. M. (2020). Cyber warfare & inadvertent escalation. Daedalus, 149(2), 133– 149. https://doi.org/10.1162/daed_a_01794

Anastassov, A (2021). Artificial intelligence and its possible use in international nuclear security law. Papers of BAS Humanities and Social Sciences, 1(8), 92-103.

Akiyama N. (2021) AI Nuclear Winter or AI That Saves Humanity? AI and Nuclear Deterrence. In: von Braun J., S. Archer M., Reichberg G.M., Sánchez Sorondo M. (eds) Robotics, AI, and Humanity. Springer, Cham. https://doi.org/10.1007/978-3- 030-54173-6_13

Axelrod, R & Keohane, R. (1985). Achieving Cooperation under Anarchy: Strategies and Institutions. World Politics, Vol. 38, No. 1, pp. 226-254.

Bengio, Y.; Courville, A.; Vincent, P. (2013). Representation Learning: A Review and New Perspectives. IEEE Transactions on Pattern Analysis and Machine Intelligence. 35 (8): 1798–1828.

Boulanin, V., Saalman, L., Topychkanov, P., Su, F. & Carlsson, M.P. (2020). Artificial Intelligence, Strategic Stability and Nuclear Risk. Stockholm Peace Research Institute.

Boulanin, V. & Verbruggen, M. (2017). Mapping the Development of Autonomy in Weapon Systems. Sweden: Stockholm International Peace Research Institute.

Chyba, C. F. (2020). New technologies & strategic stability. Daedalus, 149(2), 150– 170. https://doi.org/10.1162/daed_a_01795

Cimbala, S. J., The Dead Volcano: The Background and Effects of Nuclear War Complacency, Westport, Conn.: Praeger, 2002.

David, R. A., & Nielsen, P. (2016). Defense science board summer study on autonomy. Defense Science Board Washington United States.

Dunn, L. A. (2017). The strategic elimination of nuclear weapons: an alternative global agenda for nuclear disarmament. The Nonproliferation Review, 24(5-6), 401-435.

Fihn, B. (2017) The Logic of Banning Nuclear Weapons, Survival, 59:1, 43-50, DOI: 10.1080/00396338.2017.1282671. https://doi.org/10.1080/00396338.2017.1282671

Horowitz, M. (2019). Artificial intelligence and nuclear stability. In V. Boulanin (Ed.), The impact of artificial intelligence on strategic stability and nuclear risk, Volume 1: Euro-Atlantic perspectives (pp. 79–83). SIPRI.

Horowitz, M. C., Scharre, P., & Velez-Green, A. (2019). A stable nuclear future? The impact of autonomous systems and artificial intelligence. arXiv preprint. arXiv:1912.05291

Il-Soon, H. & Ji-Sun, K. (2019). The environmental impact of nuclear-powered autonomous weapons. In: Saalman, L. The impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. East Asian Perspectives. Vol. II, Sweden: Stockholm International Peace Research Institute.

Jadoon, U. I. (2021). The Security Impact of the Treaty on the Prohibition of Nuclear Weapons. In Nuclear Non-Proliferation in International Law-Volume VI (pp. 365-383). TMC Asser Press, The Hague.

Jervis, R. (2014). Deterrence and perception (pp. 57-84). Princeton University Press.

Keohane, R. O.(1984). After Hegemony: Cooperation and Discord in the World Political Economy. Princeton, N.J.: Princeton University Press.

Geist, E., & Lohn, A. J. (2018). How might artificial intelligence affect the risk of nuclear war?. Rand Corporation.

Le Bras, R. J., Vaidya, S., Schneider, J., Russell, S., & Arora, N. (2010). Status of the Machine Learning Efforts at the International Data Centre of the CTBTO. COMPREHENSIVE NUCLEAR TEST BAN TREATY ORGANIZATION VIENNA (AUSTRIA) PREPARATORY COMMISSION.

Lodgaard, S. (2010). Nuclear disarmament and non-proliferation: towards a nuclear- weapon-free world? (p. 288). Taylor & Francis.

Lieber, K. A., & Press, D. G. (2017). The new era of counterforce: Technological change and the future of nuclear deterrence. International Security, 41(4), 9–49. https://doi.org/10.1162/ISEC_a_00273

Lieber, K. A., & Press, D. G. (2020). The myth of the nuclear revolution: power politics in the atomic age. Cornell University Press.

Lupovici, A. (2021). The dual-use security dilemma and the social construction of insecurity. Contemporary Security Policy, 1-29.

Mazarr, M. J. (2021). Understanding Deterrence. NL ARMS Netherlands Annual Review of Military Studies 2020, 13-28.

Onderco, M. & Zutt, M. (2021) Emerging technology and nuclear security: What does the wisdom of the crowd tell us?, Contemporary Security Policy, 42:3, 286-311, DOI: 10.1080/13523260.2021.1928963

Perrow, C. (1984). Normal Accidents. Living with high-risk Technologies. New York: Basic.

Potter, W. C., & Mukhatzhanova, G. (2008). Divining nuclear intentions: A review essay. International Security, 33(1), 139-169.

Roy, K. (2020). Rationales for introducing artificial intelligence into India's military modernization programme. In: Topychkanov, P. (Eds). The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. Volume III. South Asian Perspectives. Sweden: Stockholm International Peace Research Institute.

Rotolo, D., Hicks, D., & Martin, B. R. (2015). What is an emerging technology? Research Policy, 44(10), 1827–1843. https://doi.org/10.1016/j.respol.2015.06.006

Russell, S. & Norvig, P.(2003) Artificial Intelligence. A Modern Approach. London: Pearson Education.

Saalman, L. (2019). Introduction. In: Saalman, L. (Eds). The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. Vol. II. Sweden: Stockholm International Peace Research Institute.

Schelling, T. C. (1966). Arms and Influence. Yale University Press. http://www.jstor.org/stable/j.ctt5vm52s

Schmidhuber, J. (2015): Deep Learning in Neural Networks: An Overview. Neural Networks. 61: 85–117.

Thiebes, S., Lins, S., & Sunyaev, A. (2020). Trustworthy artificial intelligence. Electronic Markets, 1-18.

Van Wyk, J. A., Kinghorn, L., Hepburn, H., Payne, C., & Sham, C. (2007). The international politics of nuclear weapons: A constructivist analysis. Scientia Militaria: South African Journal of Military Studies, 35(1).

Von Braun J., Archer M.S., Reichberg G.M., Sánchez Sorondo M. (2021) AI, Robotics, and Humanity: Opportunities, Risks, and Implications for Ethics and Policy. In: von Braun J., S. Archer M., Reichberg G.M., Sánchez Sorondo M. (eds). Robotics, AI, and Humanity. Springer, Cham. https://doi.org/10.1007/978-3-030-54173-6_1

Wong, Y. H., Yurchak, J. M., Button, R. W., Frank, A., Laird, B., Osoba, O. A., Steeb, R., Benjamin, H. & Bae, S. J. (2020). Deterrence in the age of thinking machines. RAND Corporation.

Johnson, J. (2019). The AI-cyber nexus: implications for military escalation, deterrence and strategic stability. Journal of Cyber Policy, 4(3), 442-460.

Verbruggen, M. (2020). The extensive role of artificial intelligence in military transformation. In The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk: Volume III South Asian Perspectives (pp. 11-16). Stockholm International Peace Research Institute (SIPRI).

Williams, H. (2020). Remaining relevant: Why the NPT must address emerging technologies. Centre for Science and Security Studies, King's College London. https:// www.kcl.ac.uk/csss/assets/remaining-relevant-new-technologies.pdf.

Xiang, L. (2019). Artificial intelligence and its impact on weaponization and arms control. In: Saalman, L. (Eds). The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. East Asian Perspectives. Vol. II, Sweden: Stockholm International Peace Research Institute.

Links

Bauer, S. (2020). New Technologies and Armament: Rethinking Arms Control. Clingendael Magazin. Retrieved from: https://spectator.clingendael.org/en/publication/new-technologies-and-armament-rethinking-arms-control (September 28, 2021).

Boulanin, V. (2018). AI & Global Governance: AI and Nuclear Weapons – Promise and Perils of AI for Nuclear Stability. United Nations University. Center for Policy Research. Retrieved from: https://cpr.unu.edu/publications/articles/ai-global-governance-ai-and-nuclear-weapons-promise-and-perils-of-ai-for-nuclear-stability.html (September 29, 2021).

Department of International Cooperation Ministry of Science and Technology China, 2017). China Science & Technology Newsletter. Retrieved from: http://fi.china-embassy.org/eng/kxjs/P020171025789108009001.pdf (September 21, 2021).

Major General Sheppard, D. (2007). "This Week at War," CNN, February 24, 2007. Retrieved from: http://transcripts.cnn.com/TRANSCRIPTS/0702/24/tww.01.html (September 18).

The White House (2018). Summary of the 2018 white house summit on Artificial Intelligence for American Industry. Retrieved from: https://trumpwhitehouse.archives.gov/wp-content/uploads/2018/05/Summary- Report-of-White-House-AI-Summit.pdf?latest (October 2, 2021)

Spindel, J. (2020). Artificial intelligence and nuclear weapons: Bringer of hope or harbinger of doom? Retrieved from: https://www.europeanleadershipnetwork.org/commentary/bringer-of-hope-or-harbinger-of-doom-artificial-intelligence-and-nuclear-weapons/ (September 26, 2021).

United Nations (1995). Treaty on the Non-Proliferation and of Nuclear Weapons (May 11, 1995). Retrieved from: https://www.un.org/disarmament/wmd/nuclear/npt/ (September 27, 2021).

Shattuck, L.G. (March 11, 2015). *Transitioning to Autonomy: A human systems integration perspective. IHMC Definitions. Naval Postgraduate School. Retrieved from:* human-factors.arc.nasa.gov/workshop/autonomy/download/presentations/Shaddock%20. pdf (Accessed June 2016.) (October 3, 2021).