Chapter 8 Understanding the Threat of Nuclear, Biological and Chemical Warfare

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A changing world society

The perception that biological, chemical and nuclear weapons posed existential threats largely ended with the Cold War. With the entering of the new millennium, however, we have seen several breaches of the norm against the use of biological and chemical warfare agents in the United States, Syria, Malaysia and the United Kingdom. And although the global stocks of nuclear weapons are only about a fourth of what they were at the peak of the Cold War, the breakdown of bilateral nuclear arms control between the two nuclear superpowers, Russia and the United States, may point to a second era of nuclear arms racing. This is exacerbated by attempts to develop and deploy missile defence systems in the sea, land and space domains, which challenges the mutual vulnerability on which the strategic balance is based. The consolidation of North Korea as a *de facto* nuclear weapons state only adds to this rather dim picture of the developments in the later years.

Furthermore, several political, social, economic and technological trends are redefining the global security landscape (Allied Command Transformation, 2017; Development, Concepts and Doctrine Centre, 2018). Primarily, we see a transition in power from the West to other regions, mainly to Asia, leading to intensified competition and increased likelihood of conflicts between major powers. As a result, the relevance of international organisations that provide the framework for the existing liberal world order is challenged. In addition, the security threats are cross-sectoral and we see the use of a range of non-military means such as cyber-attacks, misinformation ("fake news"), propaganda and other subversive activities that are designed to erode trust in governments and institutions, create uncertainty and stir up grievances (Development, Concepts and Doctrine Centre, 2018; cf. chapter 10). This makes it difficult to attribute who is the perpetrator and to implement effective countermeasures. We also see a diffusion of power from governments to non-state actors, challenging governments' ability to implement adequate security regulations and maintain national autonomy over important technologies (Allied Command Transformation, 2017).

With the decline of the liberal world order, and the simultaneous rise of authoritarianism in several world corners (Allied Command Transformation, 2017; Development, Concepts and Doctrine Centre, 2018), the bulwarks of international law preventing the proliferation and use of biological, chemical and nuclear weapons are under pressure.

Technological developments that may increase the future threat

Digital transformation of our society will provide many opportunities for increased efficiency, economic growth and improved quality of life which has led to an intense competition between USA, EU and China to become the world leader in digital technologies. The numerous benefits come with an increased dependency on technology and ubiquitous connectivity. This may introduce new

vulnerabilities to our critical infrastructures that are yet to be understood (Rinaldi et al., 2001; Chang, 2009; Oughton et al., 2018). Technological advancements and the unprecedented availability of online knowhow may incite the nascence of novel ways for state and non-state actors to acquire and utilize the world's most dreaded weapons as well as disrupt previously well-understood homeland security scenarios.

The complexity of today's information and communications systems implies that no country is self-reliant in hardware acquisitions. In every computing center, cloud storage facility, and military command and control center there is hardware consisting of components from a wide range of countries. We have already experienced media coverage about alleged hacking attempts through insertion of miniscule microchips on computer subcomponents. As these found their ways to a number of advanced servers in major computing companies, including a subcontractor to the CIA, it supposedly enabled Chinese surveillance of sensitive US security activities (Robertson and Riley, 2018). Already more than a decade ago, another cyber-related supply-chain vulnerability came to light in Iran. As part of a broader campaign (cyber and otherwise) to impede Iran's contested uranium enrichment efforts, US and Israeli services managed to tailor an extremely advanced computer virus that found its way across the air gap to destroy at least a thousand spinning gas centrifuges in the underground halls in Natanz. At least one of the attack vectors was allegedly a subcontractor who inadvertently brought the worm on a thumb drive to the industrial process control computers in the enrichment facility. Another was straight out spies, who maneuvered their way into the sensitive facility (Winer, 2019). Independent cyber security analysts dubbed the worm "Stuxnet", and it was later revealed to be part of a broader wave of cyber-attacks against Iran's enrichment efforts called "Olympic Games" (Sanger, 2012).

Although these examples of cyber vulnerability in strategic sectors were attacks that were focused and specifically tasked to something else, it raises the concern that advanced actors may someday succeed in compromising strategic command and control systems, potentially triggering a nuclear war between two adversaries. Nuclear-armed states that rely on a launch-under-attack doctrine are reliant upon early warning systems of imminent, or more likely, incoming ballistic missile attacks. In such a dire event, the process from detection to commanding a retaliatory launch can take no longer than the flight time of the incoming missiles after detection. In the case of Russia and the US, that is expectedly no more than half an hour for ground-based intercontinental ballistic missiles (ICBMs). ICBMs usually serve the role as first-strike nuclear weapons in strategic warplanning. The response time could be significantly shorter if the missile attack came from a strategic submarine. In any case, imagine someone decides to launch a retaliatory strike based on information appearing on a computer comprised of thousands of components from a large number of companies from around the world.

The reemergence of a nuclear menace

In the first decade after the Cold War, global nuclear arsenals shrunk as Russia and the US implemented arms reduction and arms control agreements with mutual verification measures. Trust developed between former adversaries. Both parties cut their deployed, strategic nuclear warheads and delivery vehicles through the implementation of the Strategic Arms Reduction Treaty (START, effective from 1994) (Federation of American Scientists, 1998), the Strategic Offensive Reduction Treaty (SORT, effective from 2003) (U.S. Department of Defense, 2002) and the New START (effective from 2011) (U.S. Department of State, 2010). The latter put a limit of 1550 deployed, strategic warheads and 700 deployed ballistic missiles and strategic bombers, and included trust inducing on-site inspections and other transparency measures. In contrast, both the Soviet Union and the US

had nuclear stockpiles exceeding 30 000 total warheads each at some point during the Cold War (Natural Resources Defense Council, 2006).

The trust between the two major nuclear powers generated in the 1990s eroded gradually during the next two decades, resulting in the abandonment of the 1972 Anti-Ballistic Missile (ABM) Treaty (U.S. Department of State, 1972) in 2002, the 1990 Treaty on Conventional Armed Forces in Europe (CFE) (Organization for Security and Co-operation in Europe, 1990) in 2007 and the 1987 Intermediate-Range Nuclear Forces (INF) Treaty (U.S. Department of State, 1987) in 2019. Furthermore, international efforts to bring into force the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT) (U.S. Department of State, 1996), and to conclude negotiations of a Fissile Materials Cut-off Treaty (FMCT) (to halt production of weapons-useable uranium and plutonium), have been in vain. On the other hand, every state except India, Pakistan and North Korea have adhered to a norm against nuclear testing since the CTBT opened for signatures in 1996. Along with these developments, in 2003 North Korea became the first state to withdraw from the Nuclear Non-Proliferation Treaty (NPT) (United Nations, 1968), and subsequently develop and test nuclear weapons. Between 2006 and 2018, Pyongyang performed six underground nuclear tests, including one likely thermonuclear about ten times as powerful as the 1945 Hiroshima and Nagasaki nuclear bombs. In addition, they developed and flight-tested a number of different ballistic missiles, including one with sufficient range and payload capacity to hold at risk major US population centers with a thermonuclear warhead (Kippe, 2019).

In the same period, Iran developed sensitive nuclear technology outside of the international verification regime (International Atomic Energy Agency, 2020). This provided Iran with a ripe option of rapidly breaking out of the NPT and developing nuclear weapons deliverable by ballistic missiles. Many have feared that such an event would spark a proliferation cascade in the region, potentially leading to a handful of nuclear-armed states in the Middle East. Iran and some major world powers subsequently negotiated the 2015 “Iran Nuclear Deal.” The purpose of the so-called “Joint Comprehensive Plan of Action” (JCPOA) was to limit the bomb-making capacity of Iran’s nuclear dual-use facilities, enhance the scope, intrusiveness and frequency of international verification measures (conducted by the International Atomic Energy Agency, IAEA), and to remove the related United Nations sanctions resolutions against Iran (U.S. Department of State, 2015). By 2020, the JCPOA was on life support following from the 2018 US withdrawal and subsequent re-imposition of sanctions, and since 2019 a series of reciprocal steps by Iran to stop implementing key limitations on especially its uranium enrichment efforts. Combined with a growing interest in nuclear power in the Middle East, notably by Saudi Arabia, Turkey and the United Arab Emirates, the threat of regional nuclear arms racing seems far from gone.

Back in 26 September 1983, world destruction seemed at hand when a lieutenant colonel in the Soviet Air Defense Forces, Stanislav Petrov, observed what appeared to be a US nuclear surprise attack on his early warning satellite monitor. Had he simply followed regular procedures, he would have reported directly through the command chain all the way to Chairman Andropov, who had little reason to do anything other than ordering a response in kind against the US (Chan, 2017). While this false signal had a physical explanation (the sun’s reflection on a cloud layer was mistaken for a rocket motor exhaust), it is possible to conceive of an intended “cyber spoof” being the source in a similar situation today. A comparable incident occurred in the US only four years earlier. Back then, the error source was a staff member feeding the computer with a tape containing an attack simulation instead of a clean tape (The National Security Archive, 2012).

In the days of these two chilling, but by no means singular, incidents, both the US and the Soviet Union may conceivably have relied upon only domestic hardware and software for their strategic

command and control systems. That is an increasingly unlikely situation today and in the near future. Relying on non-domestic technology introduces a vulnerability to spoofing, and in the worst case even outside tampering, in strategic command and control systems. The costs of mitigating such a threat is tremendous, as few if any states are completely self-reliant in high technological information systems.

Lately, several of the established nuclear weapons states have expressed a renewed interest in low-yield nuclear weapons. Proponents view them as essential instruments of "escalation control" and of potential non-strategic use, *i.e.* in battlefield precision strikes. The idea of escalation control is to dissuade an adversary from further escalation by crossing the nuclear threshold in a way that does not necessarily entice the recipient to retaliate in kind, for instance by taking out one particular military target of substrategic value. However, many strategic analysts express serious doubt as to whether it is possible to control escalation once a state has crossed the nuclear threshold. Imperfect situational awareness will likely drive the escalation dynamic up the ladder, rather than down. The absorbing side of a "nuclear de-escalatory strike" would be expected to experience a significant internal pressure to retaliate, both from a punishment perspective and possibly from a "use'em or lose 'em" logic (cognizant of the risk that the next incoming strike may be a disabling one on its own nuclear forces). The onus would thus be on the attacker to convince the recipient that this was not merely the first wave of a comprehensive nuclear exchange. The risk of failure in either strategic communication or strategic calculation is obvious.

The emergence and proliferation of advanced and cheap communication and sensor technology (geospatial, airborne and ground based) may enable states subject to nuclear attack to establish a more complete situational awareness than what was possible during the earlier years of the Nuclear Era. With an information stream coming from national technical means, such as military satellites and ground- and sea-based radars, as well as from open sources (such as commercial satellites and social media), decision-makers may get an early warning of an imminent attack, and may easier establish a preliminary damage assessment in the aftermath of a strike. However, they are also more vulnerable to information operations and false alarms. Fortunately, Russia and the US extended the New START Treaty by five years just before its expiration in February 2021. If they do not agree on a successor treaty with proper verification by the end of February 2026, the two nuclear superpowers will gradually suffer from a degradation of ground truth information about the other party's operational, strategic nuclear weapons. This could exacerbate the risk of a strategic miscalculation leading to an unsolicited nuclear war.

Furthermore, as more states introduce or re-introduce substrategic ("battlefield") nuclear weapons, which may be launched by delivery vehicles that otherwise carry conventional weapons, the threat of strategic miscalculation increases. Conversely, some states already deploy conventional warheads on strategic delivery vehicles, such as the Chinese, intermediate-range ballistic missile Dong Feng-26 (Center for Strategic and International Studies, 2020), and more are planning to follow suit (notably the US with its "Conventional Prompt Global Strike" programme (Congressional Research Service, 2020)). Analyst James Acton *et al* (2017) have dubbed this blurring of the distinction between the conventional and nuclear sectors "nuclear and non-nuclear entanglement," and include dual-use command, control, communication and information systems in their analysis. They warn specifically about the risk of establishing conventional, long-range, precision-guided weapons capabilities targeting an adversary's nuclear forces. A conventional counter-force attack against a state without its own such capabilities, they argue, may induce a nuclear response, inadvertent escalation and all-out nuclear war.

We have pointed out that the on-going technological development in some respects may be detrimental to strategic stability, and in other ways contribute to it through increased transparency. Furthermore, we have noted that the demise of nuclear arms control not only will precipitate a renewed emphasis on nuclear weapons, but also will enable, and even usher, the development of new and more destabilising weapon types. In concert with the development of more capable conventional weapons, some even sharing platforms with nuclear weapons, the threat of strategic miscalculation and inadvertent escalation will likely increase. Adding to this threat is the loss of on-site inspections associated with abandoned arms control arrangements such as CFE, INF and New START, which reduces Russia's and the US' mutual, ground-truth understanding of each other's strategic and other forces.

Bioterrorism and Global Catastrophic Biological Threats

Disease has through all of history been seen as the soft belly of society, and has been a major factor in reorganizing it through pandemics like the "Black death", smallpox and the influenza pandemics, most famous of which is the 1918 one, and epidemic outbreaks of cholera, typhus and others (cf. chapter 4). Surprisingly many of the services we are used to having (drinking water, garbage removal, sewage systems, pasteurization etc.), and not just the vaccines we are offered, are aimed specifically at preventing the spread of debilitating epidemics. Producing and disseminating pathogenic agents that are able to circumvent these systems and their associated controls (for instance the use of coliform bacteria as indicators of faecal pollutants in drinking water) would at best significantly reduce the public perception of security, at their worst cause massive epidemics and societal disruption.

Epidemic diseases have historically been seen as an instrument of punishment from the gods, and it was with the advent of microbiology and the understanding of microorganisms and mechanisms of disease (an understanding that is still in its puberty) that the idea that Man could direct the effects of diseases against others matured. This was seen as a very dangerous development, and was the subject of international treaties beginning with the Hague conventions of 1899 and 1907, developing through the Geneva protocol of 1925 (which prohibited the use of disease as a weapon of war) and developed into the "Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction" of 1975 (The Biological and Toxins Weapons Convention or BTWC) in which the signatories agreed to abstain from developing weapons based on microorganisms or their toxins. Since the convention still does not have any control mechanisms, it can be debated how successful it has been, seeing that several countries have had or are suspected of having biological weapons programs (NTI, 2015). Most of these nations have now destroyed their biological weapons, but the knowledge of how to develop and use them is still there, and growing in parallel to the exponential development in molecular genetics and synthesis (AC/323(HFM-186)TP/669) .

One of the defining criteria if an agent of disease is to make a predictable impact is that the targeted population does not have previous exposure to the agent. Agents that cause disease in animals are especially valuable in a biological warfare programme because of this, with agents like anthrax, plague, typhus and swine brucellosis being developed as weapons/effectors: agents causing high morbidity and mortality via the aerosol route, no or little previous exposure that would give immunity.

The object of biological weapons use was to render a nation weak and susceptible to a take-over by the perpetrator whilst minimising damage to infrastructure. They were seen as exceedingly

dangerous, not least because their production did not demand an extensive industrial base: in this sense, they could be called “the poor nations` atomic bomb”. Biological weapons were not restricted to direct use against a population, agents that would impact agricultural production and reduce food availability were also developed, as were agents that caused material degradation. Biological weapons therefore constitute a global catastrophic threat (Schoch-Spana *et al.*, 2017).

Consequently, biological weapons were seen as population killers as well as battlefield weapons, and as such complemented nuclear weapons in that they could destroy societies while leaving the infrastructure intact. In order to be useful as weapons there were criteria that had to be fulfilled so that their effects could be exploited: They should not spread efficiently from person to person outside the target area, they should be able to infect through the airways as an aerosol as this is the most efficient and predictable method of infecting large numbers, and they should have predictable, debilitating or deadly effects within a defined time-frame. Used to effect they could kill perhaps 20% of the target population and cause staggering disease numbers that would overwhelm any health services.

Interest in biological warfare is still present, and while most of the interest is defensive and related to early detection and medical countermeasures, there is a growing awareness of the molecular mechanisms that cause disease, and ways to exploit these. This is knowledge that may be utilised to cause harm. Confronting the threat of bioterrorism is therefore of utmost importance (Green *et al.*, 2019).

In addition, both development in molecular genetics and the understanding of how biological agents interact with organisms to cause disease cause proliferation concerns. The cheap and easy access to a variety of bespoke oligonucleotides, *i.e.* short DNA or RNA molecules, or even (parts of) complete genomes or virulence factors moves the ability to change the properties of a virus or bacterium from the large, national laboratories to smaller, private enterprises with less controls and containment. This moves the ability to produce significantly pathogenic or virulent microorganisms or vectors into a world no longer necessarily adhering to conventions and national or international controls (Schoch-Spana *et al.*, 2017; DiEuliis & Giordano, 2018). Malevolent use of biotechnology may therefore create novel global catastrophic threats, such as targeted population threats, novel strains of known contagious pathogens, widespread eradication of food sources, or novel or artificial organisms that are harmful to the existing life (Schoch-Spana *et al.*, 2017).

Countering the threat associated with biological weapons and novel biological agents demands international agreement on controls on implementation of relevant treaties, agencies that oversee and prevent proliferation of knowledge and materiel that might be used to develop such agents and not least public health programmes that reduce the effects of all contagious disease.

Preventing chemical weapons use

World War I (WWI) unleashed large-scale use of chemical weapons. By the end of WWI, the use of chemical weapons had resulted in around 90,000 fatalities and 1.3 million casualties (OPCW, n.d.). Following the post-WWI negotiations, the use of chemical weapons in war was banned with the signing of the 1925 Geneva Protocol (OPCW, n.d.). The Geneva Protocol did not, however, prohibit the development, production or possession of such weapons. Many nations therefore researched toxic chemicals, resulting in the accidental discovery of nerve agents in 1936 by German scientists. Quickly after, the Nazi armed forces started to secretly weaponize nerve agents and other chemical agents. In 1943, Nazi-Germany had produced a total of 44,764 tonnes of chemical agents (Tucker,

2006; Everts, 2016). Although Nazi-Germany never used chemical weapons at European battlefields, it used toxic chemicals to kill millions of Jews during the Holocaust.

After the World War II (WWII), the USA, the United Kingdom and the Soviet Union started to research the nerve agents developed by the Nazi-Germany. It was not until the Soviet Union managed to develop their own nuclear weapons that the chemical weapons arms race started to intensify. Since it was no longer possible for the USA to threaten with nuclear weapons without facing the risk of mutual destruction, USA felt a need to reinforce nuclear deterrence by what was considered as a "retaliation-only" chemical warfare capability (Tucker, 2006). During the Cold War, the USA and the Soviet Union stockpiled and maintained tens of thousands of tonnes of chemical warfare agents (OPCW, n.d.).

Since the end of WWII, chemical weapons have been used at several occasions, especially in the Middle East. There is substantial evidence that the Egyptian government initiated their chemical weapons program in the early 1960s (Shoham, 1998; Tucker, 2006; Quillen, 2017). In the fall of 1962, following the death of Yemen's king Imam Ahmed bin Yahya, Egypt decided to support a group of Yemeni military officers' efforts to overthrow the monarchy and replace it with a republican government modelled on Egypt's regime. However, Imam Ahmed's son managed to escape and rallied tribes in the northern parts of the country as well as support from Saudi Arabia. As a result, the Egyptian intervention became much more costly and longer than first anticipated because of difficulties of fighting Yemini royalists that operated out of mountain caves. Egypt therefore started to experiment with the use of chemical weapons even though it had signed the 1925 Geneva Protocol. During the North Yemen Civil War that lasted until 1970, Egypt used chemical weapons on several occasions until they had to withdraw from Yemen in 1967 following Egypt's defeat in the Six-Day War with Israel (Tucker, 2006; Quillen, 2017). Despite credible reports, the international community and the UN did little if anything to investigate or stop Egypt's violations of the 1925 Geneva Protocol.

Inspired by Egypt's chemical weapons use in Yemen and driven by a need to counter the regional power of Israel and Iran, the Iraqi regime launched their own chemical warfare program in 1971 (Tucker, 2006; Quillen, 2017). After the Iranian revolution in 1979, the Iraqi regime hoped to take advantage of Iran's post-revolutionary chaos and replace Iran as the dominant Persian Gulf state. Iraq therefore launched a massive military attack on Iran in 1980 but was pushed back by Iran who launched a counter-invasion of Iraq in 1982. Until the UN-brokered ceasefire was accepted in 1988, Iran was on the offensive. The Iraqi regime therefore resorted to chemical weapons use (Duelfer, 2004). In 1987 Iran also started to use chemical weapons to retaliate the Iraqi chemical attacks (Director of Central Intelligence, 2010). Even though both Iraq and Iran were state parties to the 1925 Geneva Protocol, this did not stop them from using chemical weapons.

Close to the end of the Iran-Iraq war, on 16th March 1988, the Iraqi regime launched a massive chemical attack on Halabja, Iraq. The attack was a genocide of the Kurdish people living there, resulting in more than 4000 civilian fatalities (Human Rights Watch, 1993; Mlodoch, 2017). This horrible incident together with the improved relations between the USA and the Soviet Union in the late 1980s and the risk of chemical warfare during the Gulf War, gave urgency and momentum to the negotiations on the Chemical Weapons Convention (CWC) which had been on-going since 1968 (OPCW, n.d.).

On 13th January 1993 the CWC was opened for signature in Paris. Within the first two days, 130 nations signed the CWC. As of 16th June 2018, 193 nations are state parties to the Convention, one signatory state has not yet ratified the CWC (Israel) and three states are non-signatory parties

(OPCW, 2018). The three non-signatory states are Egypt, North Korea and South Sudan. In 2017 South Sudan announced that they will join the CWC (OPCW, 2017). Egypt have stated that they will join the CWC when the Middle East is free for weapons of mass destruction, while Israel maintain its position that joining the CWC is linked to general security considerations in the region (Eaves, 2014). When it comes to North Korea, they are not expected to join the CWC in the foreseeable future (Eaves, 2014).

The CWC has two important principles: the "General Purpose Criterion" (GPC) and the verification mechanism. The GPC distinguish between legitimate and prohibited applications of chemistry and technologies related to production of chemical weapons. The verification mechanism, on the other hand, obliges every state party to the CWC to destroy its chemical weapons stocks and production facilities, and allow inspections of any industrial facility that could be used for purposes prohibited under the CWC. Thus, the CWC fixed many of the shortcomings of previous chemical disarmament efforts.

Since the CWC entered into force on 29th April 1997, significant progress has been made in non-proliferation and verifiable disarmament of the world's declared chemical weapons. Despite this, chemical weapons have been used in Iraq, Syria, Malaysia and United Kingdom since 2012.

Until 14th October 2013, Syria was a non-state party to the CWC. Syria was, however, a state party to the 1925 Geneva Protocol. Beginning in late 2012, allegations of chemical weapons use in Syria started to surface, but no credible evidence were found (Trapp, 2017). The allegations reached a "tipping point" in March 2013 when the Syrian government officially requested the UN Secretary-General to investigate an alleged chemical attack in Khan Al Asal on 19th March 2013 (Pita & Domingo, 2014; Trapp, 2017; Edwards & Cacciatori, 2018). As a response to the request, a UN Mission was established under leadership by the Swedish scientist Åke Sellström. Shortly after, France and United Kingdom, and later USA, reported that chemical weapons had been used at several other locations in Syria (Trapp, 2017). It took, however, months before Sellström's team could enter Syria, arriving just days before the large-scale chemical attack in Ghouta on 21st August 2013.

Sellström's team concluded that chemical weapons have been used in five of the seven investigated alleged incidents, including in the 21st August 2013 attack in Ghouta (Sellström *et al*., 2013a; Sellström *et al*., 2013b). Despite President Obama's statement in 2012 that use of chemical weapons would cross a "red line", no military interventions were taken in the aftermath following the Ghouta attack. Instead a window of opportunity opened for a disarmament of the Syrian chemical weapons stockpile, leading to Syria's accession to the CWC on 14th September 2013 (Lewis & Tertrais, 2017; Trapp, 2017; Edwards & Cacciatori, 2018). Unfortunately, the disarmament of the Syrian chemical weapons stockpile did not deter further chemical weapons use in Syria. Instead, the chemical attacks continued (OPCW, 2017; UN News, 2017).

Since 2018, several measures have been adopted by the state parties to the CWC to address the threat from chemical weapons use (OPCW, 2018). Firstly, the OPCW has established an Investigation and Identification Team that shall identify perpetrators of the use of chemical weapons in Syria. Secondly, the OPCW shall upon request from a state party that is investigating a possible use of chemical weapons on its territory, provide "technical expertise to identify those who were perpetrators, organisers, sponsors or otherwise involved in the use of chemicals as weapons". Thirdly, the OPCW should enhance the capacity and tools to strengthen the implementation of the CWC verification regime as well as provide options for further assistance to state parties when it comes to enhanced chemical security. Lastly, following the incident with an unscheduled nerve agent

in United Kingdom, new toxic chemicals have been added to the CWC annex on chemicals (OPCW, 2019).

Given these measures and the progress with destruction of the world's declared chemical weapons stockpile, what are the prospects for future chemical weapons use? Based on the short historical account provided, a few remarks can be made. First of all, as was evident already since WWI, chemical weapons are only effective against unprotected persons. Chemical weapons have therefore almost exclusively been used against unprepared civilians or military forces in armed conflicts since WWII (Quillen, 2017). Furthermore, experiences from previous incidents have shown that chemical weapons are of limited military utility, even in the civil war in Syria (Chapman *et al.*, 2018).

Still, given that toxic chemicals have been used as weapons for thousands of years, there are no reasons to believe that this threat will disappear any time soon. A worrying future scenario is the large-scale use of novel central nervous system (CNS) acting chemicals for law enforcement purposes by an authoritarian regime in order to suppress a civilian uprising against the regime. The potency of such chemicals was demonstrated in the Dubrovka theatre hostage crisis in Moscow in 2002 (Riches *et al.*, 2012). Although the use of riot control agents for domestic law enforcement is not prohibited under the CWC, the range of permissible chemicals have not been established. Use of CNS-acting chemicals as weapons therefore poses a significant challenge to the CWC (Shang *et al.*, 2018).

A way forward?

The exponential growth in complexity constitutes a major challenge for small states, trying to cope with emerging existential threats through their security policy, legislation, and education. Raising public awareness of the key drivers and prerequisites for this potential development is necessary to for society to tackle it. Conversely, so-called developed states need to come to terms with the dissipation and cost reduction of advanced technology. Recent decades have provided the major powers with ample experience in underestimating the technological potential of developing states. While the superpowers during the Cold War sometimes overestimated the capabilities of their counterparts, they more often underestimated emerging states. This mind set merely makes states susceptible to future strategic shocks, the kinds of which we may only speculate.

Reliable information on the development, design and production of nuclear weapons has been in the public domain for decades. The genie hardly remembers the bottle. To avoid a cascade of nuclear proliferation, the most effective strategy is to bolster international and multilateral agreements and controls (such as the NPT and its associated transparency requirements), to ensure that weapons-useable fissile materials in non-nuclear weapons states are under the IAEA's most rigid verification regime. The anticipated nuclear power renaissance and the erosion of the liberal international order both challenge this goal.

When it comes to reducing the threat of future chemical or biological weapons use, several measures are needed. First, protection of civilians in addition to military forces is of utmost importance in order to deter future use. Secondly, the CWC and the BTWC need to continue to strengthen, so does the control of transfer of knowledge, technology and material. Thirdly, it is important that those who plan or carry out chemical or biological weapons attacks are brought to justice. This requires novel attribution capabilities since perpetrators may attempt covert use of chemical or biological weapons to avoid repercussions. Lastly, it is necessary to increase our knowledge and awareness about such weapons, the goals of the CWC and the BTWC and the importance of responsible scientific practice.

To prepare the society for these developments, it is important to have a science-based understanding of the threats. This may entail abandoning Cold War notions of technological

bottlenecks, damage potential, likely usage *et cetera*. Only then are we able to prioritize and adopt the most cost-effective preventive and responsive measures tailored for a new future. Here, proper education can provide an important basis for scientific and critical thinking among the next generation of decision makers, which is key for any rational threat assessment.

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