Metis

Study

Conventional arms control and emerging technologies

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Summary

The verifiability of limits or bans on countable units of military hardware is a key element of successful arms control. A number of new technologies, however, do not lend themselves to this quantitative approach. This study looks at hypersonic glide vehicles, autonomy in weapons systems and brain-computer interfaces as examples of new and emerging technologies and points out the need for regulation before going on to discuss how qualitative arms control can meet these new challenges.

One step forward, two steps back

Some say that arms control is only possible when it is unnecessary – and impossible when it is actually necessary. As clever as that sounds, it does not stand up to scrutiny.

In the best-case scenario of a security community between states, it is true that arms control is not necessary (anymore). In the worst-case scenario – war – it is virtually impossible. And the more strained relations are, the more difficult it is to mobilise the political will for (additional) arms control. But as long as neither of these two extremes come true, which, in reality, they only rarely do, arms control is both possible and necessary because it is an effective way to develop relations away from war and conflict and across the spectrum towards a security community.

The tensions between the major powers of the United States, China and Russia are making progress in the area of arms control difficult. Nuclear arms control is in its deepest crisis since the beginning of the nuclear age,[1] and a lack of political will means that, in recent years, conventional arms control has not fared much better either.

The Arms Trade Treaty, which came into force in 2014, is the most recent milestone of conventional arms control. It established rules and international standards for arms exports. Since then, however, there have been several steps backwards. One such example from a European perspective is the multilateral Treaty on Conventional Forces (CFE). Its adapted version never came into force and the original one was effectively terminated by Russia in 2015. Russia's extensive rapid exercises this summer alone suggest that there is actually an urgent need for more effective tools for transparency and confidence building in Europe, not least in light of the Ukraine conflict and the protest movement in Belarus. Furthermore, US President Trump (at the time of writing) still intends to withdraw from the multilateral Open Skies Treaty, which allows observation flights to ensure transparency. As a result, the remaining 33 contracting states are left asking if and how the treaty can continue to function without US participation. At the United Nations (UN) level, government expert talks on cyberspace have stalled and little progress is being made in the further development of space law.[2]

What is more, the arrival of high technology in the conventional armaments sector is giving rise to increasing entanglement between the nuclear and the non-nuclear domain. For the longest time, the only threat to nuclear weapons were, to somewhat simplify things, other nuclear weapons. Now, new conventional rockets, hypersonic missiles and other unmanned (networked) systems are becoming increasingly relevant to strategic stability.

1 See "Nuclear arms control in crisis", Metis Study No. 18 (August 2020).

2 See "Space security", Metis Study No. 13 (August 2019).

There is thus a greater need for regulation and progress in conventional arms control.

The current geopolitical situation makes progress in arms control difficult yet all the more necessary, which is why Germany has in recent years been actively working to preserve and advance conventional arms control, particularly in light of certain technological advances and their potentially far-reaching implications for stability and security. It soon became clear that one fundamentally changed parameter creates challenges that require us to rethink arms control.

***Fig. 1** Titan II missile components at the Aerospace Maintenance and Regeneration Center, Davis-Monthan Air Force Base in Tucson, Arizona.*

From quantity to quality

To recap: The purpose of arms control between states is to stabilise relations and to develop trust. It prevents wars and, in an emergency, limits damage. It frees up resources that would otherwise have to remain tied up in the armaments sector for other governmental purposes.

Verification traditionally plays an important role in conventional arms control. It serves to ensure compliance with treaties, either through mutual verification by the parties to a treaty or through a dedicated international organisation created specifically for this purpose. Information on compliance with a treaty is continually obtained, collected and assessed so that violations can be detected and breaches are disincentivized.

This means that, by extension, effective verifiability increases the political incentive to commit to a treaty because it dispels fears of betrayal. It is not for nothing that the old adage of arms control is: "Trust, but verify."

Traditional arms control ensured verifiability based on a quantitative paradigm. It established (categories of) weapons to be technically defined and then counted, restricted, reduced or prohibited those. In many areas of arms control – whether conventional or nuclear arms, anti-personnel mines or nuclear warheads – effective verification continues to rely on countable units. Countability creates transparency creates verifiability creates control, so to speak.

A number of new technologies are now causing problems when it comes to this countability. After all, if military capabilities are determined more by quality than quantity, e.g. if the degree of networking and autonomy achieved through software is more relevant than the mere number of systems, then the quantitative arms control paradigm reaches its limits. Such internal attributes cannot be determined from the outside during the sort of on-site hardware checks that are typical of traditional arms control. Twenty unmanned weapons systems are easy to count – but what if they can operate in an autonomous swarm and thus represent an increase in military capabilities that is greater than the sum of its (twenty) parts?

Arms control was never limited to just the quantitative paradigm alone, of course. In other words: The absence of countable units and thus of verification measures that rely on them is nothing new in some areas. The chemical and biological weapons regimes, to name just the two most important examples, have always faced this issue. Some lessons can be drawn from this for the final section of this study, which addresses recommendations for action. To illustrate the problem and how it affects conventional arms control, however, we will first examine three examples and their resulting implications.

New technologies: Three examples

Example 1: Hypersonic glide vehicles (HGVs)

Hypersonic glide vehicles are re-entry vehicles for ballistic rockets which use aerodynamic lift in the high upper atmosphere to achieve greater range and manoeuvrability. Speeds of up to Mach 20 are nothing new. Warheads of ballistic rockets have always been that fast. What is new, however, is the twofold ambiguity that currently characterises HGVs. First of all, their target is ambiguous. Since they do not follow a ballistic trajectory, their destination remains unclear for quite some time. Their warhead is also ambiguous. HGVs are still in a grey area because there are no firmly established expectations yet when it comes to the type of warhead they carry – conventional or nuclear. Some countries are developing systems equipped with conventional warheads, some with nuclear warheads, others aim for dual-capable systems. So it is not the new delivery system in itself that poses a challenge, but rather the still undetermined purposes and uses. While strategic ballistic rockets are usually equipped with nuclear warheads (apart from a few attempts to convert them to conventional warheads, such as the US Prompt Global Strike programme), no such established practice has emerged for HGVs yet.

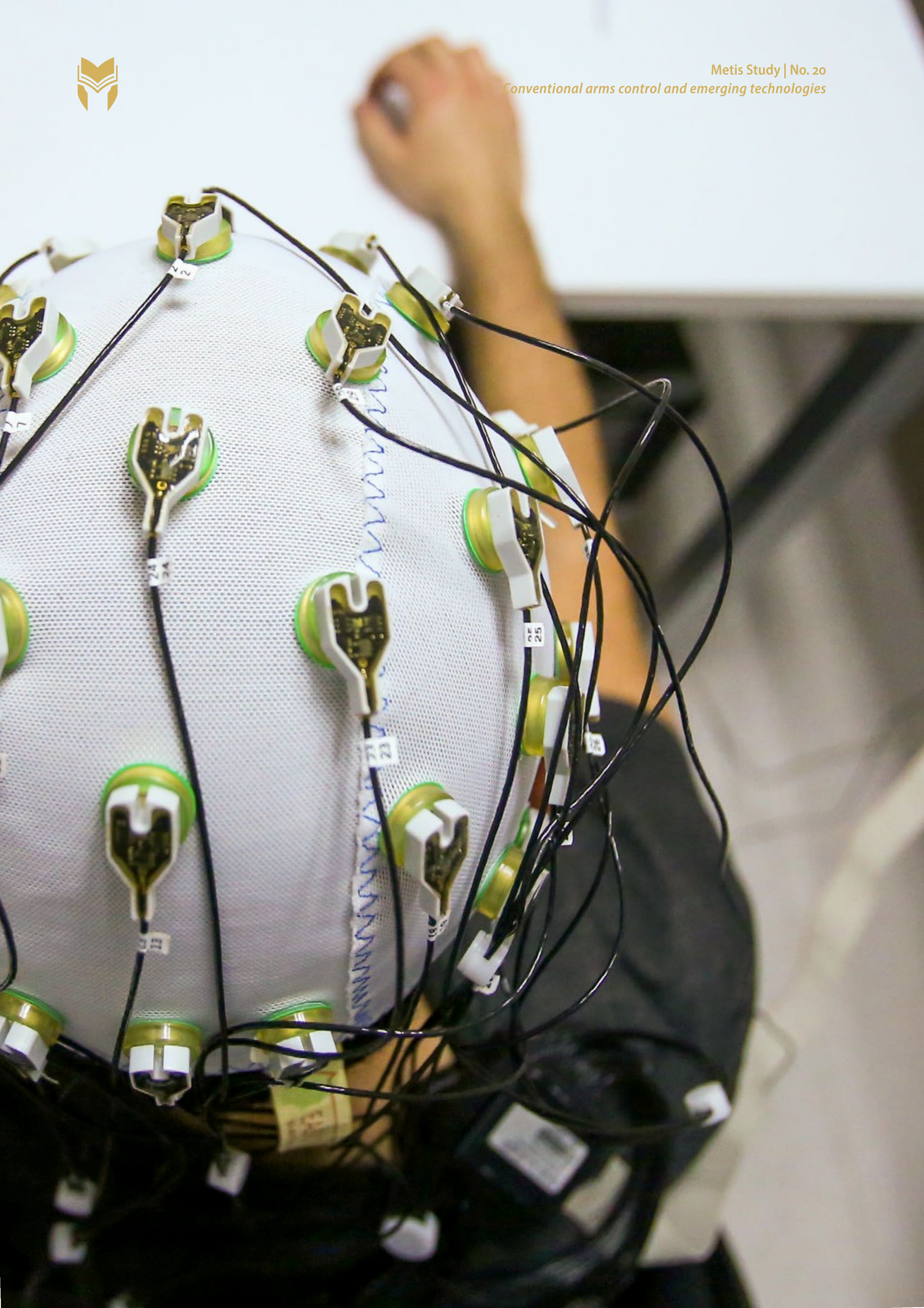
Example 2: Autonomy in weapons systems (AWS)

Weapons systems can already perform numerous functions without human control. A good example is the targeting cycle, which includes six phases: find, fix, track, target, engage, assess. A weapons system can be considered fully autonomous if it goes through this entire cycle of decisions and functions, including the target engagement stage, without human intervention or even human supervision.[3] In the future, many weapons systems could become fully autonomous in this way. The capability of independent machine function is achieved primarily through software. In principle, all driving, flying, floating or submerging weapons systems can thus be enabled not only to navigate independently but also to find and engage targets without human intervention. Autonomy in the “critical” functions of target selection and target engagement is neither entirely new nor a bad thing per se. In terminal defence systems, for example, autonomous operation at machine speed is a useful life-saving feature. But in other contexts, autonomy in critical functions poses operational, legal and ethical risks. As suggested above, a system equipped with autonomous functions is not necessarily identifiable as such from the outside. The degree of dependence on human control – and thus the potential operating speed – may be determined by something as simple as a click in the weapons systems’ user interface. In short, when it comes to AWS, the quantitative paradigm is very limited in its effectiveness.

Example 3: Brain-computer interfaces (BCIs)

Neuroscience is a cross section of several research areas with a focus on understanding the brain and interacting with it. Recent breakthroughs included imaging methods and more efficient interfaces with computers. The research and development incentives for such BCIs are as great as they are diverse. They range from the hope of finding treatments for degenerative brain diseases to business ideas for virtual entertainment and a great many military applications. One possible military application of BCIs is the integration of neuronal activity of the human brain with weapons systems. Because despite all technological progress, the human brain – a sensor fusion system that has evolved and improved over thousands of years – can still perceive and assess threats much faster and more reliably than a computer can in many situations, particularly in confusing, complex and unclear circumstances. However, a weapons system can be selected and activated much faster by a machine controlled via a BCI than via traditional human (remote) control. Reducing the role of human cognition raises legal and ethical questions not unlike those associated with AWS. Here too, the transparency issue is problematic. Traditional verification methods such as external inspections cannot determine how a weapons system or a swarm of systems is controlled and what capabilities it features.

3 See “The security-policy effects of digitisation: Future forms of conflict and conflict management”, Metis Study No. 1 (February 2018).



Operational, legal and ethical implications

All three examples have the key factor of speed in common and, for all three, capability enhancement and operational improvements must be balanced against the risk of putting human cognition and control at stake. Specifically, the following three implications must be considered.

Risks of escalation

From the perspective of the party that is being attacked, the type of warhead attached to incoming HGVs makes a considerable difference. In the event of a nuclear attack, for example, the incentive to retaliate immediately, i.e. before the second-strike arsenal is compromised, is much greater than the incentive to just "ride out" the attack. The ambiguity surrounding the warheads of HGVs thus represents a lack of transparency that creates crisis instability and carries a risk of unintended, potentially nuclear, escalation. Autonomous weapons systems have a similar implication, as their positive effect when it comes to missile defence turns negative in other fields of application. The threat of unintended escalation is also inherent in these systems, because, without a human acting as a "circuit-breaker", it is of course not just the targeting cycle that works faster, i.e. at machine speed, but also any unintended escalation – unstoppable through human intervention – if the machine has made an error.

Accountability gaps

Autonomous weapons systems and brain-computer interfaces face the same problem in terms of international law. Current law of armed conflict was formulated with neither machines nor human-machine hybrids in mind. When BCIs are used for weapons systems, the effect of the weapon, in a way, is triggered reflexively and not fully consciously. It is thus unclear to what extent such a system would be compatible with the fundamental premises of international law of war: human agency and responsibility. If, for example, the principles of distinction and proportionality were to be violated, could the person linked to the interface even be considered fully responsible? That question is even more urgent when it comes to autonomously operating weapons systems, which may see no human involvement for hours or days at a time.

Norm violations

There are also parallels between BCIs and AWS from an ethical perspective. There is, for example, the question whether the human in a human-machine hybrid system is reduced to the role of a mere raw material for weapon production – the human brain is downgraded, in a manner of speaking, to the status of an additional module for weapons systems. AWS represent the flip-side of that ethical coin because here, anyone killed by an AWS is downgraded to an object and robbed of their human dignity. The enemy is dehumanised and reduced to a data point to be processed by anonymous algorithms on the battlefield.

Recommended courses of action and prospects

In light of the security, legal and ethical implications outlined above, the need for regulation is clear. This need has to be addressed differently for all three examples.

Hypersonic glide vehicles (HGVs)

Because existing arms control treaties and, by extension, established expectations regarding the use of this new type of weapon do not cover HGVs, the quantitative paradigm does not either – at least as of yet. Issues of transparency and verification are relatively easy to deal with, however. A multilateral treaty on a test moratorium for hypersonic vehicles would be a possible – if ambitious – arms control tool that would be easy to verify. Confidence-building measures such as prenotification of tests or exchanges of weapon telemetry data could also be an option. Mutual declarations on types of warheads would also serve to increase transparency.

In contrast, the two applications that are based on military use of civilian innovation – weapons system autonomy and brain-computer interfaces – show that a quality achieved primarily through software requires a different approach than the one that is appropriate for HGVs. At the same time, however, it is clear that these two technologies, which open up different military fields of application and advantages, pose similar or overlapping problems and risks.

We can conclude that the focus should thus be on the implications of the military use of dual-use technologies rather than on these technologies themselves. In other words, qualitative arms control must prioritise the establishment of robust, binding, future-proof norms and rules of conduct for responsible development and utilisation before addressing the hardware, if at all. After all, banning technology is usually neither practicable nor desirable.

Autonomy in weapons systems (AWS)

The international community of the UN has been discussing weapon autonomy since 2013, in particular in talks at the UN Weapons Convention in Geneva. So far, the aim of this exchange has not been to achieve a legally binding result. It has not yielded any tangible results beyond reaching an agreement on eleven guiding principles, according to which human responsibility must be preserved in the clarification and further development of the normative and operational framework for interaction between humans and weapons systems. A legally binding document that firmly establishes human control over the use of violence as a principle of international law, for example as an additional protocol to the UN Convention on Certain Conventional Weapons, could be a possible product of the Geneva process, although that seems unlikely given the current geopolitical situation. Agreeing on a politically binding code of conduct that obliges all parties to not delegate life-and-death decisions on the battlefield to machines would require less political will. Another possible achievement would be to expand reviews of new weapons systems with autonomous functions in accordance with Article 36 of Protocol Additional I of the Geneva Convention. A minimum consensus would be to exchange best practices for the entire life cycle of autonomous weapons systems, i.e. to develop an internationally shared understanding of how human control can be retained in the design and operation of such systems – through tactics, techniques and procedures depending on the operational context.

Brain-computer interfaces (BCIs)

Norms of behaviour are also key when it comes to BCIs in particular and, more generally, the military use of neuroscientific dual-use technologies. Considerations of biosafety and biosecurity established as part of the Bioweapon Convention could serve as a basis. The task of safeguarding "neurosecurity" requires awareness-raising and establishing codes of conducts for scientists as well as independent risk assessments. Another possible option would be to establish a "principle of cognitive liberty" in order to ensure that unauthorised intrusion into human autonomy, privacy and mental integrity is socially stigmatised and politically banned.

Two steps are necessary for the further development of qualitative arms control. Firstly, the current silo mentality must be dismantled and the increasing overlap between conventional weapons and weapons of mass destruction must be taken into account. Secondly, arms control must become more open to new technologies and determined to take advantage of them for its own purposes. Initial attempts, though tentative, are numerous. Image recognition methods based on machine learning can identify mines on ground radar images as well as components that are subject to export control. In combination with distributed-ledger technologies (of which blockchain technology is the most commonly known example), they can also detect violations against safeguards of the International Atomic Energy Agency in atomic plants. Commercial providers of satellite images now deliver up to two images of every location on earth every day. Such open-source intelligence permits verification of the sort that used to be the preserve of states. In summary, arms control will only play a role in the 21st century if it comes to regard new technologies not only as something to be regulated but also as new and promising tools to embrace.

Fig. 2 *The United Nations' Convention on Certain Conventional Weapons discussing weapon autonomy in Geneva.*

Photo: author

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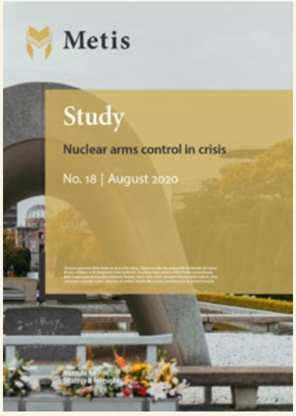

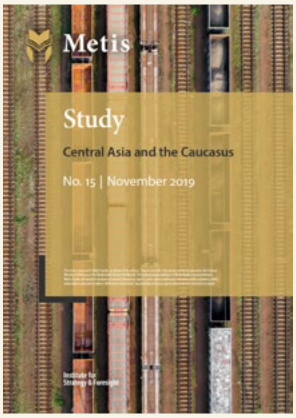

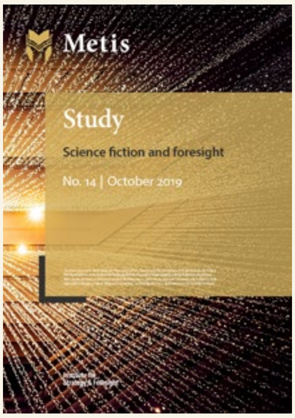

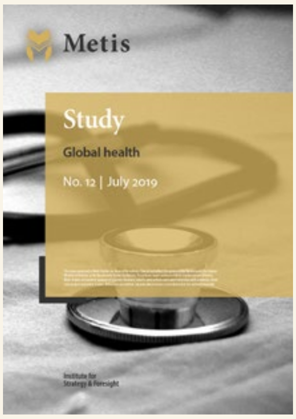

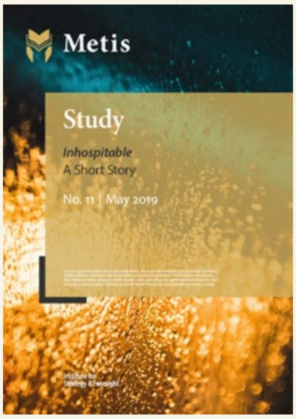

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