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Blockchain Technology: An Innovative Policy Tool for Enhancing Conventional Arms Control and Verification

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The Organization for Security and Co-operation in Europe (OSCE), jointly with the Institute for Peace Research and Security Policy at the University of Hamburg (IFSH) and in partnership with the Geneva Centre for Security Policy (GCSP), Moscow State University of International Relations (MGIMO) and the Vienna Centre for Disarmament and Non-proliferation (VCDNP), has launched an "OSCE-IFSH Essay Competition: Conventional Arms Control and Confidence- and Security-Building Measures in Europe". The project aims at facilitating the continuity of knowledge and expertise on arms control and CSBM processes at the OSCE among students and recent graduates interested in peace and security studies. This essay has participated in the 2021 competition and has been awarded the first prize ex-aequo.

Key Points

- Blockchain represents an unprecedented opportunity for enhancing conventional arms control (CAC) and verification. Based on the principles of transparency, verifiability, and predictability, this state-of-the-art technology could build confidence and facilitate the implementation of arms control mechanisms.
- Blockchain-based so-called "smart contracts" have advantageous practical implications for CAC. They could improve the verification of countries' compliance with their CAC obligations by enhancing monitoring procedures and could strengthen arms export controls by improving treaty signatories' ability to monitor weapons and ammunition supply chains.
- Reinforcing the Organization for Security and Cooperation in Europe (OSCE) framework for conventional ammunition control with a permissioned blockchain would provide greater confidentiality and improve monitoring and data verifiability, thus strengthening the OSCE's CAC regimes.

About the Author

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Introduction

Blockchain has the potential to revolutionise our societies by radically transforming multiple sectors ranging from financial services to health care, and from international trade to logistics.[1] Governments, businesses, research centres, and international organisations are becoming increasingly interested in this cutting-edge technology because it can be utilised to provide a decentralised system for data management with high levels of transparency, reliability, and security.[2] Recently, inter-governmental organisations such as the United Nations (UN) and the OSCE have emphasised the relevance of blockchain, which can be utilised to improve international security.[3]

Blockchain has already proved that it can effectively enhance human security.

Blockchain has already proved that it can effectively enhance human security. For instance, the World Food Programme has pioneered a blockchain-based humanitarian aid programme to support refugees in Jordan with the use of cryptocurrencies.[4] Similarly, the International Committee of the Red Cross has developed a distributed ledger technology (DLT)-based local trading system in Kenya to help fragile communities.[5] In 2015 the UN International Children's Emergency Fund even launched "Unicoin" – its own cryptocurrency – which children from poor families can exchange for goods.[6]

Although researchers have been exploring the impact of this technology on multiple fields, the implications of blockchain-based systems for CAC are still under-explored. This paper aims to fill this research gap by demonstrating that blockchain can play a crucial role in enhancing CAC monitoring and verification. It argues that blockchain offers a positive behavioural model and has advantageous practical implications for conventional arms control. The analysis is guided by the following research questions: (1) what psychological impact does blockchain have on confidence building? and (2) how do smart contracts enhance CAC?

Research design

The paper draws on secondary sources such as government documents, publications in academic journals and reports produced by research centres. The analysis is based on a multidisciplinary approach that considers the fields of sociology, international relations, and economics. Consequently, the study explores not only how blockchain can practically enhance CAC, but also the positive psychological impact this technology can have on countries' behavioural patterns.

The paper does not aim to address the technical aspects underlying the functioning of blockchain. It is instead intended for policymakers who might not have a background in DLTs but are interested in exploring the opportunities that they offer. To the knowledge of the author, currently there are no examples of international blockchain-based CAC regimes. Therefore, this paper is theoretical and based on the actual use of blockchain in other fields such as business, administration, and health care.

Traditional challenges to arms control regimes

Although arms control regimes differ in various ways, such as the number of parties involved, the weapons subjected to agreements and the monitoring procedures, control mechanisms face some key common challenges. These issues concern not only the practical enforcement of verification procedures, but also the behavioural patterns of countries regarding arms control.

A pivotal problem concerns the psychology of arms control. Countries develop and implement arms control regimes only if certain conditions are met. Arms control necessitates a balance between the requirement for transparency in states' military postures and their need for security.[7] If countries perceive arms control verification as too pervasive and as a potential cause of involuntary – or voluntary – leaks of sensitive information, their governments are unlikely to enforce arms control regimes, because they feel threatened.[8] For instance, inspecting the weaponry stored in a military base could lead to the disclosure of data that renders facilities more vulnerable to attacks. Similarly, arms export control regimes can be undermined by psychological factors. Countries are not incentivised to enact arms control agreements if non-compliance cannot be effectively detected and breaches of the agreements are not severely penalised.[9] This erodes confidence in the system, which is increasingly believed to be unreliable, and disincentivises countries from implementing the agreed controls.

Arms control necessitates a balance between the requirement for transparency in states' military postures and their need for security.

Furthermore, arms control agreements suffer from practical constraints such as difficulties with verification procedures. Governments and international organisations are increasingly struggling to effectively track and trace small arms and ammunition along the supply chain, because they are often produced and assembled in different countries.[10] This limits their ability to comprehensively monitor imports and exports of weaponry, because it has become increasingly difficult to collect data on each stage of weapons production, storage, transportation, and purchase. In similar vein, the effective verifiability of conventional arms control agreement remains a major issue. For example, states can intentionally undermine or prevent the verification of troop numbers, deployments, and capabilities. Similarly, countries might prolong the period between a request for inspection and the arrival of inspecting teams to prevent the detection of cases of non-compliance with CAC treaties.[11] The declaration of off-limits areas serves a similar purpose.[12] Governments may also delay the issuing of visas in order to temporarily prevent inspectors from entering the country, allowing a state time to cover up evidence of its non-compliance.

These major challenges can be effectively tackled by developing blockchain-based arms control regimes. Indeed, this technology offers unprecedented opportunities to build confidence between countries and provide practical solutions to enhance arms control regimes. However, blockchain should not be viewed as a universal panacea, and is instead a tool to mitigate the challenges arms control regimes face, but it cannot prevent them entirely.

Key blockchain features

Blockchain emerged in 2008 when a person or group of people working under the pseudonym of Satoshi Nakamoto invented Bitcoin.[13] The Bitcoin cryptocurrency is currently the best-known use of blockchain[14] but this technology is also being applied to sectors other than financial services such as administration and trade.[15] Although different types of blockchain exist, some key common innovative aspects characterise this technology.

As a type of DLT, blockchain is a digital tool for recording and sharing data across multiple data stores – the "ledgers" – which are monitored and verified by a distributed network of computers – the "nodes".[16] Data is verified and added to a blockchain through cryptography and mathematical algorithms that ensure the validity and immutability of the information.[17] Blockchain users are responsible for adding and verifying data transfers. By using two digital keys – one private, one public – the nodes send, receive, and verify information.[18] When a node wants to add new data to the blockchain, this data first needs to be validated according to the established consensus mechanism. The two most used consensus mechanisms are the proof of work (PoW) and proof of stake (PoS) mechanisms[19] – respectively better known as "mining" and "forging".[20] These are cryptographic validation processes that guarantee the correct sequencing of transactions on the ledger.[21]

Blockchain is a digital tool for recording and sharing data across multiple data stores – the "ledgers" – which are monitored and verified by a distributed network of computers.

Because the digital ledger is a peer-to-peer network, it enables direct interactions between all senders and receivers and reduces the role of intermediaries, simplifying the execution of transactions.[22] However, this largely depends on the type of blockchain. While a *permissionless* blockchain like Bitcoin can be joined by any user who can send, receive, and validate information, a *permissioned* blockchain restricts access to only authorised users according to agreed parameters and charges only a few nodes of the validation process.[23]

Given its features, this technology can revolutionise the field of arms control. Its impact is not limited to practical issues such as data management and control but could also affect countries' approach to arms control.

Blockchain as a positive behavioural model for CAC

Arms control would not be possible if key shared basic criteria are not established by the parties to a CAC agreement. A high level of confidence between countries is a determinant of effective arms control.[24] In light of this, blockchain can provide one of the most effective behavioural models for building confidence and enhancing CAC mechanisms.[25]

Academics suggest viewing blockchain as a "confidence[-building] machine" that "creates shared expectations with regard to the manner in which it operates, and the procedural correctness of its operations".[26] This technology reduces the need for trust[27] among parties by enhancing the reliability of the system. In the case of CAC, the adoption of blockchain can benefit the relationships between the parties involved by building confidence through the systematisation of transparency, verifiability, and predictability. These three factors constitute a positive behavioural model and build confidence (see Figure 1).

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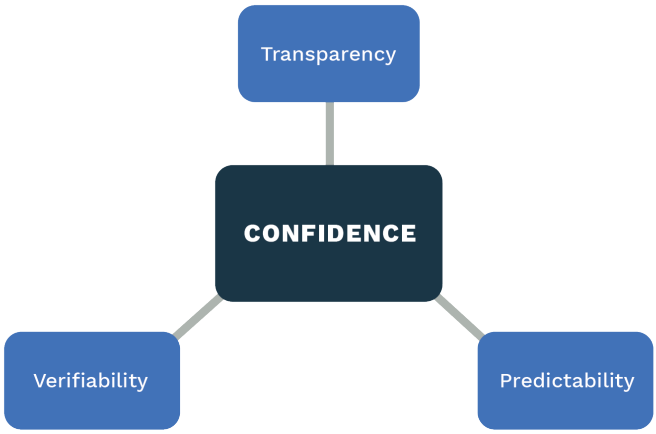
Figure 1. Key confidence-building factors: transparency, verifiability and predictability



Transparency, verifiability, and predictability are cornerstone principles of any arms control regime. The transparent availability of data offers empirical evidence of countries' conventional arms stocks and military capabilities.[28] This not only includes information on military forces and weaponry, but also data on military doctrines and defence budgets, which are key elements underlying states' respective military postures.[29] However, transparency will not be sufficient to build confidence if compliance with arms control obligations cannot be verified. Data on arms control therefore needs to be accessible using established and clear procedural tools that support monitoring and investigations into arms agreement breaches.[30] Finally, predictability is a pivotal factor influencing relationships between governments. Among other things, arms control agreements are aimed at allowing countries to make assumptions about their adversaries' military strategies and plans.[31] Uncertainty regarding other countries' military intentions is a fundamental negative factor that can accelerate the escalation of conflict between states.[32]

Blockchain can strongly enhance transparency, verifiability, and predictability. Not only does the digital ledger ensure the availability of

information, but it also makes data immutable and provides constant access to it. This greatly increases transparency, thus facilitating positive relationships between countries. Moreover, such data would be verified through shared consensus mechanisms that require countries to test the truthfulness of any new information that is about to be added to the blockchain. Any node can access the information recorded on the ledger and is therefore able to continuously verify the blocks of data. Finally, the hashing algorithm and the ledger's mathematical protocols would ensure high levels of predictability because it is possible to foresee the output for any given input.[33] Countries' ability to comprehensively assess historical and current data on military arsenals, capabilities, and doctrines reduces uncertainty and strengthens participating states' insight into and understanding of the behavioural patterns of the other signatories of an arms control agreement. Ultimately, states are enabled to better foresee the outcome of other states' potential inputs (e.g., weapons, doctrines, and military budgets).

Blockchain can lead to a highly positive behavioural model that can be viewed as a policy tool with the ability to transform arms control agreements.

As a result, blockchain can lead to a highly positive behavioural model that can be viewed as a policy tool with the ability to transform arms control agreements.[34] It is able to ensure transparency, verifiability, and predictability, which are key behavioural and communication principles that can build confidence among countries and pave the way for the development of agreements and procedures for CAC. Ultimately, blockchain psychologically incentivises countries to implement arms control mechanisms.

Smart contracts: the practical impact of blockchain on CAC

Blockchain has multiple practical implications for efforts to enhance CAC. This technology guarantees the better monitoring and verification of international agreements and improves control of the arms supply chain.[35] Blockchain-based smart contracts have the potential to revolutionise CAC procedures by automating the detection of anomalies and strengthening export controls.

Smart contracts are computer programmes that automatically self-execute as the pre-agreed conditions of an agreement are met.[36] These blockchain-based solutions are attracting the attention of international organisations such as the UN and the World Trade Organisation, which are testing their application in multiple fields.[37] Such contracts provide constant verification of compliance with obligations and accelerate the settlement of disputes.[38] Moreover, they reduce the risk of malicious exceptions because clauses can be pre-established and signatories' obligations made clearer.[39]

Smart contracts can enable the automation of detection procedures.

In the field of CAC, smart contracts can enable the automation of detection procedures. Cases of non-compliance can be easily detected, and protocols and processes for tackling such non-compliance can be speeded up. This can be achieved by combining blockchain and the Internet-of-things (IoT). After pre-agreeing the location of a weapons storage site in a smart contract, items such as light weapons or ammunition can be provided with IoT-based geolocational devices that continuously signal their location.[40] If these items are moved out of the facility or area, the smart contract would register an anomalous location signal and warn the parties involved.[41] This can improve and simplify verification procedures, because they do not need to be carried out on the ground. Indeed, teams can track the arms from remote locations without the need to physically inspect facilities.

Furthermore, smart contracts can strengthen the control of arms exports. These technologies have already proved to be beneficial for the purpose of gun control. Researchers have designed smart contract-based firearms registries to track and trace guns from the manufacturing stage to the purchase of the weapons.[42] This enhances the control of products and maintains comprehensive, shared registries of items. Producers, consumers, and regulatory authorities are kept continuously informed on the production, storage, and purchase of guns or ammunition, thus facilitating transactions and improving security. Potentially, such a scheme can be replicated at the international level and is under evaluation by prominent researchers to achieve this. For instance, in the United States, the Stimson Center is assessing the potential of blockchain for sensitive data management, the verification of documents and digital identities, and the traceability of items.[43] It is also exploring whether blockchain can better prevent unauthorised actors from obtaining military technology when items are exported.

A blockchain-based smart contract regime for arms exports can create a comprehensive inventory and provide access to information on the various items involved (e.g., location, characteristics, and quantity). This enables parties to continuously monitor and verify the status of the items. Because the ledger is shared in its entirety, the audit process is more efficient and can be initiated by any member.[44] Furthermore, if anomalies arise, the blockchain-based smart contract would rapidly inform the parties involved, thus speeding up verification procedures and improving accountability.

Designing a blockchain-based mechanism for CAC

In its *OSCE Handbook of Best Practices on Conventional Ammunition*, the OSCE comprehensively addresses the processes required to implement CAC, focusing in this case on ammunition.[45] These processes require governments, public authorities, and private actors to record comprehensive data on the manufacturing, storage, transport, and monitoring of ammunition.[46] Blockchain can enhance and improve the effectiveness and efficiency of these procedures by interconnecting the various features of the OSCE framework for CAC.

Such a system must be permissioned because sensitive information is recorded on the ledger. A permissioned blockchain would provide higher degrees of confidentiality by encrypting information and authorising only certain nodes as validation mechanisms.[47] Each country – the nodes – would be connected to the OSCE-permissioned blockchain-based system, which would set standards, conditions, and parameters for participating in the ledger. This DLT system would record a range of information on ammunition such as type, quantity, site of storage, and certificates of possession and transportation. Data would derive from national inventories and would be updated by the nodes that the OSCE authorises to validate information (Figure 2).

A permissioned blockchain would provide higher degrees of confidentiality by encrypting information and authorising only certain nodes as validation mechanisms.

Nodes would be incentivised to cooperate because – as explained above – blockchain provides a positive behavioural model that builds confidence. Countries would have full confidence in the correct operativity of the blockchain-based control mechanism. The OSCE DLT system would function as a transnational digital ledger that creates a comprehensive, easily accessible inventory. Data on the blockchain would result from nodes' transfers of numerous pieces of information on ammunition, e.g., manufacturing, stockpiling, certificates of conformity, financial transactions, etc. (Figure 3).

Figure 2. Graphic representation of a potential OSCE permissioned DLT system for CAC

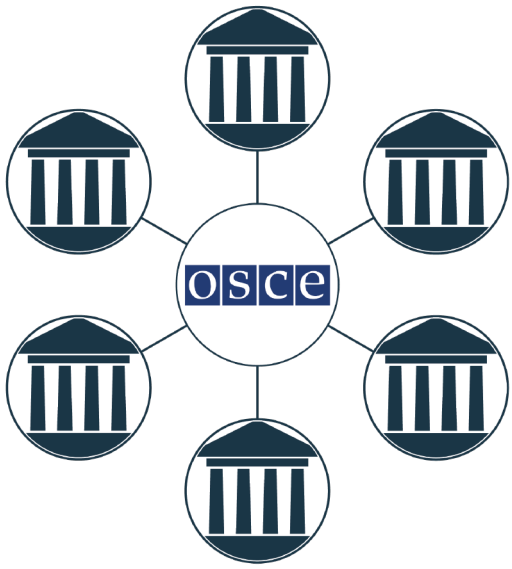
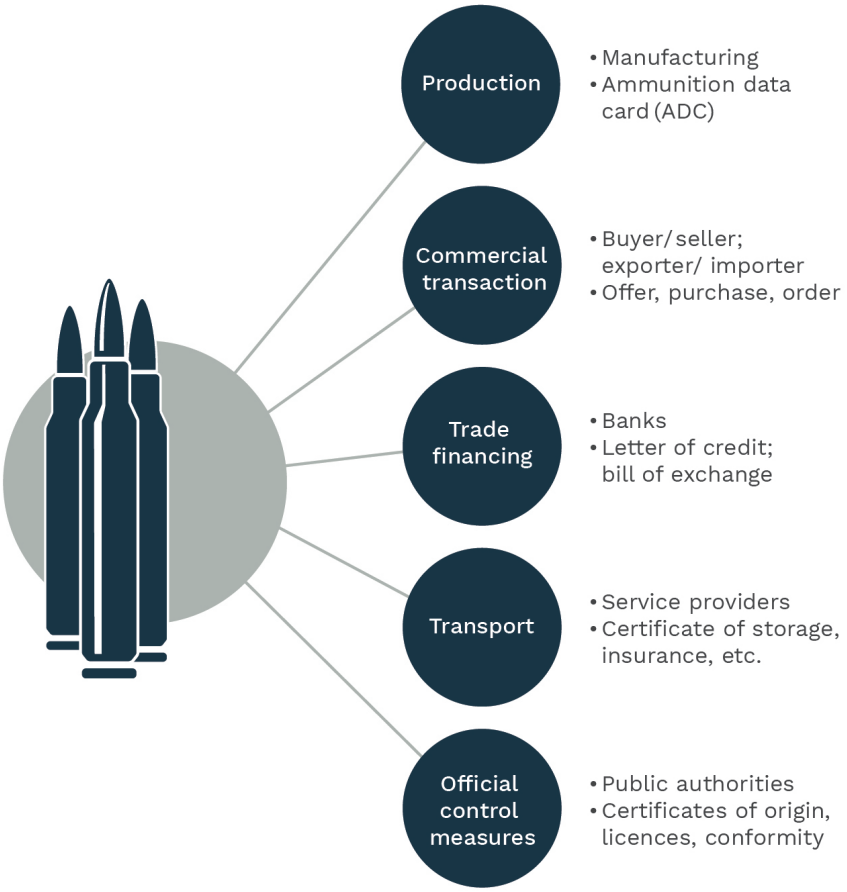


Figure 3. Data on conventional ammunition that nodes could add to the OSCE blockchain



Smart contracts between nodes within the OSCE framework would enhance auditing and verification and guarantee the accountability of participating countries.

Finally, smart contracts between nodes within the OSCE framework would enhance auditing and verification and guarantee the accountability of participating countries. For instance, a smart contract on conventional ammunition control could define the quantity of and storage sites for ammunition. By attaching IoT devices such as sensors and location tags to stockpiles of ammunition, information on the stored items could be rapidly verified from remote locations. If anomalies were detected, parties would be informed and could tackle the issues according to established procedures for investigation and dispute settlement encoded in the smart contract or already existing frameworks.

In addition, smart contracts would provide high levels of confidentiality through the use of cryptography, thus securing sensitive information such as the geolocations of items,[48] which would be revealed only to authorised nodes. The effective monitoring and securing of ammunition and weapons stockpiles are fundamental because the theft of technology is a concerning issue that negatively affects arms control regimes.[49] The smart contract could also define which actors are allowed to access storage sites while IoT-based devices such as intelligent locks and card readers would provide data on attempts to access facilities where ammunition is stored.[50] This would ensure that only authorised subjects have access to items.

Conclusions

The effectiveness of current arms control regimes is affected by a wide variety of issues. For example, countries might perceive a tension between transparency requirements and their need for security. Moreover, if verification procedures are believed to be unreliable, states are disincentivised from complying with arms control treaties. Finally, arms control regimes are negatively affected by difficulties in monitoring and tracing exports of weapons.

Blockchain can effectively mitigate these issues. This technology offers a revolutionary behavioural model that provides multiple opportunities for confidence building. By improving transparency, verifiability, and predictability, blockchain could form the basis of a system that enable states to have better knowledge of other states' military postures, constantly verify information and embrace more accurate assumptions. Furthermore, encryption can guarantee a high degree of information security that would ensure that countries' confidentiality requirements are met.

By improving transparency, verifiability, and predictability, blockchain could form the basis of a system that enable states to have better knowledge of other states' military postures, constantly verify information and embrace more accurate assumptions.

From a practical point of view, smart contracts – a blockchain-based solution – can revolutionise the detection of non-compliance with agreements and strengthen the control of arms exports. Blockchain-based registries could collect data on the entire supply chain by providing information on all the parties, documents, and steps involved in the production, transportation, storage, and purchase of weapons and ammunition. In addition, the combination of blockchain and IoT technologies could enable continuous monitoring from remote locations.

Reinforcing the OSCE framework for CAC with blockchain technology represents an example of the practical advantages DLT technology could provide to governments and international organisations. Distributed immutable digital ledgers could facilitate the monitoring of conventional arms and ammunition stockpiles by recording data from the manufacturing process to the storage of items. Smart contracts combined with IoT technologies could then ensure improved auditing and accountability by rapidly facilitating the detection of anomalies and non-compliance.

Despite the advantages that this technology offers, blockchain might be affected by cyber threats that undermine its security. However, this paper does not cover the potential issues affecting DLT cybersecurity. Hence, further research is needed to comprehensively explore the potential use of blockchain for CAC.

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