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ANALYSIS

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PROJECT D-TECT

Assessing technologies to counter the diversion of small arms and light weapons

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EXECUTIVE SUMMARY

Based on a series of stakeholder engagements, this paper examines the relevance and applicability of 14 technologies to support or strengthen efforts to counter the diversion of small arms and light weapons (SALW). The technologies examined are: 2D codes, chemical encoding, DNA coding, document authentication, electronic seals, GNSS and mobile tracking, near-field communication, radio-frequency identification, sensors, Internet of Things, distributed ledger technology, big data analysis, natural language processing, and computer vision.

All technologies were assessed as having potential relevance in helping to counter SALW diversion. The types of technologies identified as most relevant tended to differ depending on the life cycle stage (i.e., pre-export, transfer or post-delivery) and counter-diversion element (i.e., prevention, detection or identification), with technologies better suited at detecting or identifying diversion rather than preventing its occurrence. However, because the choice of a specific technology should be based on context and need, this paper does not recommend specific technologies, or a combination thereof, to help counter diversion.

Infrastructural and cost requirements were assessed as posing the highest barriers to the successful implementation of the technologies. Additionally, the adoption of a technology will also necessitate overcoming several systemic barriers. These include fragmentation among the multiple actors involved in SALW, practicalities of technology development and adoption, lack of infrastructure (digital, physical, regulatory) surrounding the technology, cost of technology, national security considerations, lack of sufficient knowledgeable personnel, and need for data and data management.

The paper provides a non-exhaustive overview of possible options which could be undertaken to overcome or mitigate these barriers, including strengthening international and regional collaboration and inter-agency cooperation, building up the evidence and knowledge base, reinforcing or establishing the appropriate physical, regulatory and digital infrastructure, and undertaking institutional capacity-building and individual training.

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Glossary

- **Components of conventional weapons (CWC)**: A component can be defined as "one of several or many units of which something is composed". In the context of conventional weapons, this refers to the different elements and items that are used to develop and build a conventional weapon. These items could be large or major components such as engines, aeroplane fuselages or turrets, but also smaller items such as electronic systems or the subcomponents used to construct the major components.

- **Diversion**: "The rerouting and/or the appropriation of . . . conventional arms or related items contrary to relevant national and/or international law leading to a potential change in the effective control or ownership of the arms and items. Instances of such diversion can take various forms: (a) An incident of diversion can occur when the items enter an illicit market, or when redirected to an unauthorised or unlawful end user or for an unauthorised or unlawful end use. (b) The rerouting and misappropriation of the items can take place at any point in the transfer chain, including the export, import, transit, trans-shipment, storage, assembly, reactivation or retransfer of the items. (c) The transaction chain facilitating a change of effective ownership and/or control can involve various forms of exchange, whether directly negotiated or brokered – grant, credit, lease, barter, and cash – at any time during the life cycle of the items."[1]

- **Small arms and light weapons (SALW)**: "'Small arms and light weapons' [are] any man-portable lethal weapon that expels or launches, is designed to expel or launch, or may be readily converted to expel or launch a shot, bullet or projectile by the action of an explosive, excluding antique small arms and light weapons or their replicas. Antique small arms and light weapons and their replicas will be defined in accordance with domestic law. In no case will antique small arms and light weapons include those manufactured after 1899: (a) 'Small arms' are, broadly speaking, weapons designed for individual use. They include, inter alia, revolvers and self-loading pistols, rifles and carbines, sub-machine guns, assault rifles and light machine guns; (b) 'Light weapons' are, broadly speaking, weapons designed for use by two or three persons serving as a crew, although some may be carried and used by a single person. They include, inter alia, heavy machine guns, handheld under-barrel and mounted grenade launchers, portable anti-aircraft guns, portable anti-tank guns, recoilless rifles, portable launchers of antitank missile and rocket systems, portable launchers of anti-aircraft missile systems, and mortars of a calibre of less than 100 millimetres."[2] Note that this definition does not include or pertain to ammunition.

- **Technology**: There is no single definition of technology. For example, the Merriam-Webster dictionary defines it in three ways: (1) "the practical application of knowledge especially in a particular area" or "a capability given by the practical application of knowledge"; (2) "a manner of accomplishing a task especially using technical processes, methods, or knowledge", and (3) "the specialized aspects of a particular field of endeavor".[3] In the context of this report, the definition of technology most closely resembles the second definition: "a manner of accomplishing a task especially using technical processes, methods, or knowledge". Specifically, the technologies within the scope of this paper are those that have been recently developed and are emerging in the context of diversion prevention, although this paper does not examine technologies at the lowest levels of readiness.

List of abbreviations

2D	Two-dimensional
AI	Artificial intelligence
ATT	Arms Trade Treaty
CWC	Components of conventional weapons
DLT	Distributed ledger technology
D-TECT	Countering the Diversion of arms using TEChnology Tools
GNSS	Global navigation satellite system
IATG	International Ammunition Technical Guidelines
IoT	Internet of Things
ITI	International Tracing Instrument
NFC	Near-field communication
NLP	Natural language processing
PoA	United Nations Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects
RFID	Radio-frequency identification
SALW	Small arms and light weapons
UN	United Nations

Section 1 - Introduction

Applying technology as one of the tools to prevent diversion

The diversion of conventional arms and related ammunition, parts and components to unauthorised end users and end uses poses a significant threat to societies around the globe. Since the late 1990s, international attention has focused specifically on the diversion of small arms and light weapons (SALW), rather than other types of conventional arms (as outlined in the box on this page), due to their use in conflict and for criminal and terrorist purposes. As a consequence, initiatives have been developed at the national, regional and international levels to counter the diversion of SALW to unauthorised end users or for unauthorised end uses. Preventing diversion is an important objective of many national export control systems and of transfer controls. It is also a key objective of several international and regional instruments that have been adopted to strengthen the regulation of the trade in specific types of conventional weapon, such as the Arms Trade Treaty (ATT), the Firearms Protocol and the United Nations Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects (PoA).

A combination of systemic and practical measures is required to effectively reduce the risk of diversion of weapon systems.[5] A range of non-technological approaches, such as information sharing, is already in place to counter diversion. While technology could also address the issue of diversion, in practice the general uptake and implementation of technologies to counter the diversion of conventional arms, ammunition and, parts and components remains relatively limited. Overall, there appears to be a gap between, on the one hand, the increasing discussions of using technologies in counter-diversion efforts and initiatives and, on the other, their effective wide-scale implementation.

Main methods for diversion of SALW[4]

SALW are at an increased risk of diversion compared to other, larger military equipment for several reasons:

- "Their **ease of use**, as SALW do not require particular technical skills or equipment to operate, making them accessible and attractive to a wide range of users, including but not limited to state and non-state armed forces, security forces, police forces, and civilians.
- The **ease of diversion** of such items, given their small size, making them 'easy to conceal'.
- Their **long life cycle**, increasing the opportunities for diversion across their lifetime.
- The **high scale of production** of SALW, which can make individual products more difficult to keep track of.

"In this context, it is also important to consider that SALW is a broad category comprising many different types of weapons. Some of these will be at greater risk of diversion, simply because they are more appealing to users. Others will pose greater risk to international security, such as man-portable air-defence systems (MANPADS) and man-portable anti-tank systems (MANPATS), due to their ability to threaten and affect larger military (and civilian) equipment to a greater extent than other SALW."

Purpose and scope of this paper

The relevance of technology to strengthening counter-diversion efforts was explored as part of the initial phase of the Countering the Diversion of arms using TEChnology Tools (D-TECT) project. Project D-TECT aims to develop and test an approach to identifying and assessing the utility and feasibility of using specific technologies for preventing, detecting, negating or mitigating the diversion of conventional weapons and their components. Project D-TECT consists of two consecutive phases:

- To identify existing technologies that could be suited to countering the diversion of conventional weapon systems, including SALW, ammunition, parts and components (hereafter referred to as "conventional weapons and related components"), and to develop a framework that makes it possible to identify and assess technologies used to counter diversion.

- To assess, refine and validate the list of technologies identified in phase 1 in relation to specific types of conventional weapon systems.

The findings and conclusions of Project D-TECT research could be relevant in the context of the different international and regional instruments that seek to enhance efforts to prevent, detect, eradicate and address diversion of SALW. In particular, these findings could have relevance in the context of ongoing processes, notably the PoA and the ATT, as well as the Firearms Protocol, the Global Framework for Through-life Conventional Ammunition Management, and relevant processes of the UN Security Council and subsidiary organs (such as its committees). As such, the primary intended audience is state authorities. Additional relevant stakeholders for whom this research is relevant include the private sector, civil society, international organisations, and all other stakeholders involved across the life cycle of SALW and components of conventional weapons (CWC). A summary of the main findings is provided below.

This paper presents findings from the second phase of Project D-TECT, which focuses specifically on the application of technology to counter the diversion of SALW. A second paper examining CWC will be released in August 2024.[7] Future phases of research will expand beyond these two specific types of items and also explore the applicability of the framework to other types of conventional weapons, components and ammunition.

This paper presents initial insights into the relevance and applicability of selected technologies to support or strengthen efforts to counter the diversion of SALW. It highlights barriers to the use of technology and possible avenues to overcome these obstacles. Drawing on the initial longlist of technologies identified in the first phase of D-TECT, 14 technologies (presented in Table 1 along with brief outlines of their various potential purposes) are at the centre of the technological assessment and the findings presented in this paper.[8]

In addition to the assessment of the aforementioned technologies, this paper and the subsequent one on CWC are intended as a proof-of-concept for the technology-assessment approach (as explained in the next section) and its utility in aiding reflection on relevant technologies within the context of counter-diversion of conventional weapons and their components.

Table 1: Longlist of technologies and their purposes

Technology	Potential purpose(s)								
	Accountability	Tracking and tracing	Item-level identification	Inventory and storage	Anti-tampering	Identification and certification	(End-use) monitoring	Data capture/recording	Data analysis
2D codes	✓	✓	✓	✓					
Chemical encoding	✓	✓	✓	✓					
DNA coding	✓	✓	✓	✓					
Document authentication						✓			
Electronic seals (e-seals)					✓				
GNSS and mobile tracking		✓							
Near-field communication (NFC)	✓	✓	✓			✓			
Radio-frequency identification (RFID)	✓	✓	✓	✓		✓			
Sensors‡						✓	✓	✓	
Internet of Things (IoT)							✓	✓	
Distributed Ledger Technology (DLT)		✓			✓			✓	
Big data analysis†									✓
Natural Language Processing (NLP)†									✓
Computer vision†									✓

‡ The wide existing range of sensors includes, e.g., cameras, radars, thermal imaging, x-ray scanners, gas indicators, acoustic sensors, time-temperature indicators, RFID, etc.

† These are subsets of artificial intelligence (AI).

Summary of key findings from phase 1 of Project D-TECT

Findings from D-TECT's first phase demonstrate that taking a **needs-driven and context-sensitive approach** to the application of technology for counter-diversion is crucial.[6] In other words, the selection of technology should not be driven by its mere availability.

A three-step framework emerged from the first phase of the research (see Figure 1). The first step focuses on understanding the risks of diversion, which are tailored to each specific type of conventional weapon and the context in which it operates. The second step examines the existing technologies that could help prevent or overcome the identified risk or risks. The third and final step assesses the identified technologies according to the contexts in which they are to be applied and also against selected attributes that the technologies should possess.

Phase 1 of Project D-TECT also identified an initial longlist of technologies (see Figure 2) that could possibly be relevant in strengthening counter-diversion efforts in international arms transfers of conventional weapons and related components. The identification of these technologies was guided by their potential relevance and their ability to counter diversion. Specifically, these technologies were selected because they are either (a) used to counter the diversion of weapons but remain limited in their use and are not widespread; or (b) used in the civilian commercial realm to increase the integrity and security of supply chains but have not been used for sensitive military or security items.

Figure 1: Framework to identify and assess technologies to counter the diversion of conventional weapons and related components

Step 1	**Specifying the aim of using technology and mapping item-specific risks of diversion.**
Step 2	**Identifying potential technologies which could help address the aim(s) and risk(s) identified in Step 1.**
Step 3	**Analysing the context in which technologies are to be implemented.**

Figure 2: Overview of technologies

Less complex technologies → **More complex technologies**

- 2D codes
- Chemical coding
- DNA coding
- Document authentication

- Electronic seals (eSeals)
- Global navigation satellite system (GNSS) and mobile tracking
- Near field communication (NFC)
- Radio-frequency identification (RFID)

- Sensors
- Internet of Things (IoT)
- Distributed ledger Technology (DLT)

- Big data analysis (AI)
- Natural Language Processing (NLP) (AI)
- Computer vision (AI)

Methodology

Project D-TECT adapted an existing methodology to frame the assessment of the longlist of technologies: the Systematic Technology Reconnaissance, Evaluation and Adoption Method (STREAM).[9] As the name indicates, this approach assesses the relevance of technologies and the possibilities of their adoption to fulfil a specific purpose. This methodology comprises five steps:

1. framing of the issue;
2. identification of technologies;
3. characterisation of the issue;
4. comparison of options; and
5. decision.

Steps 1 and 2 were the focus of the first phase of the project, while this phase focuses on steps 3 and 4.[10] Specifically, step 3 involves the following elements:

1. assessment of the potential impact of the identified technologies on countering diversion;
2. assessment of the potential barriers to the implementation of these technologies; and
3. assessment of the costs related to the implementation of these technologies.

Step 4 consists of a comparison of the technologies based on the assessment emerging from step 3.

A sequential exploratory design was used to collect the data. The project team used surveys to collect primarily quantitative data, which was then used in online expert workshops. There was a survey and an associated workshops for each of three different stages in the typical life cycle of SALW or CWC: pre-export, transfer and post-delivery. The selection and definition of these stages is further discussed in Section 2.

Ahead of each workshop, all workshop participants were invited to complete an online survey. The surveys consisted of two parts. In the first part, respondents were asked to assess the technologies' **perceived positive impact** on counter-diversion efforts for SALW and for CWC. The second part focused on the **potential barriers** to the successful implementation of these technologies, again with separate assessments for SALW and CWC. During the workshops, which took place online, the survey findings were presented and discussed, allowing the participants to elaborate on their reasoning behind their responses and to add further insights on the application of technology to counter-diversion efforts.

Participants came from a broad variety of backgrounds including national transfer control (licensing) authorities, customs and border control agencies, United Nations entities (e.g., the Office on Drugs and Crime, the Office for Disarmament Affairs), other international organisations (e.g., the World Customs Organization), regional organisations (e.g., the Organization of American States), the private sector, and research organisations. Participants were not selected for their expertise or knowledge on the technologies per se, but rather for their experience in international trade flows, arms transfer controls, and countering the diversion of conventional weapons and their components.[11] There was a different group of participants in each workshop, although some experts did take part in several workshops due to expertise in different stages. Table 2 provides an overview of the data-collection approach and participation rates.

In addition, several semi-structured interviews were conducted throughout the project. Relevant insights from these interviews, as well as conclusions drawn from a literature analysis, are used in this paper to further substantiate insights from the surveys and the workshop discussions.

Three key limitations should be noted. First, the findings are based on only a relatively small number of survey respondents and workshop participants, who form only a small subsection of the wider community involved in counter-diver-

Table 2: Overview of the data-collection approach for SALW-specific inputs

Workshop	Life cycle stage	Item types[12]	Number of survey respondents	Number of workshop participants[13]	Date
1	Pre-export	SALW and CWC	17	17	26 February 2024
2	Transfer	SALW and CWC	12	18	14 March 2024
3	Post-delivery	SALW	17	21	26 March 2024

sion of SALW. Second, while the project team sought to ensure a wide-ranging representation of perspectives from the participants in terms of background, expertise and geographical representation, most of the inputs nonetheless emerged from entities and individuals from the Western European and Other States regional group. Third, participants differed in terms of their levels of knowledge and understanding of each of the technologies, as well as the different types of needs, resources and expectations they considered when participating in the research. The findings presented below have been aggregated, and so do not allow for such differences to emerge; thus, they may not always be reflective of each individual response. Overall, the findings should be seen as illustrative rather than authoritative and should not be generalised or extrapolated beyond the constraints of this study. Despite these limitations, however, it is hoped that the findings and conclusions can nonetheless offer useful insights into the application of technology to counter-diversion efforts and can pave the way for further research and action in this area.

Report structure

Section 2 presents the overall assessment of the technologies which could be used to counter the diversion of SALW, based on the survey inputs and workshop discussions. **Section 3** then provides an overview of key systemic barriers which emerged when discussing the application of technologies to counter-diversion efforts. It also proposes possible avenues to mitigate or overcome these barriers. **Section 4** concludes the report with reflections on the key findings on the implementation of technology to aid in the counter-diversion of SALW.

Section 2 - Assessing the technologies

This section presents the main findings drawn from the surveys and workshop discussions. It provides an overview of the participants' inputs regarding the possible impact of technologies on counter-diversion of SALW, and the possible barriers that those seeking to implement these technologies might face. Before the findings are presented, the approach used to elicit them is briefly explained.

Risks and methods of diversion differ according to the type of item, the context and location, and the stage of the supply chain or life cycle.[14] Conscious of these differences, each workshop and its associated survey focused on one of three different stages of the life cycle, in addition to the two separate types of items (SALW and CWC). Within the context of this research, the stages are defined as follows:

1. **Pre-export**: This is the stage when national licensing authorities consider an application for a licence for an international transfer of SALW – i.e., post-manufacture but pre-shipment of SALW. Methods of diversion at the pre-export stage include unauthorised production, illicit removal or

theft, use of forged documents, and use of shell or front companies with a view to hide the effective end user or end use. One of the key elements of this stage is a risk assessment of the proposed transfer, which will include an assessment of the potential for diversion of the SALW. The result of the assessment will inform the government's decision whether to authorise or deny the international transfer.

2. **Transfer**: This stage is the transportation of SALW (e.g., by land, air or sea) from the country of origin to their country of destination (possibly via different transit countries), including their import into the recipient country. Methods of diversion during this stage include use of fake documentation, deliberate misdescription of the goods, rerouting of the goods at transit hubs, and smuggling or theft.

3. **Post-delivery**: This refers to the post-shipment verification, stockpiling and active use of SALW, up until their eventual disposal, including destruction. Here, methods of diversion include theft or capture, loss from stockpiles – both private and government-held – and unauthorised transfer including re-export and use.

Overall, while risks of diversion of SALW exists across all stages, the post-delivery stage is often identified as the one facing the highest risks of diversion of SALW.[15] Furthermore, diversion can be both intentional and unintentional, with one type of intentional diversion being state-sponsored diversion. Intentional diversion can be achieved through a range of methods including those described above, such as deliberate misdescription of goods or unauthorised transfer, sale, trade or gift across all stages of the SALW life cycle.[16] The next box provides reflections from participants on the utility of technology to aid with intentional diversion.

Deep dive: Reflections on the overall utility of technology to counter intentional diversion

In instances of intentional diversion, actors involved may actively seek to overcome any counter-diversion measure, whether technological or not. For example, while document-authentication technology can help to ensure authenticity of documents themselves, this technology does not inherently prevent the input of false information into the documents. Similarly, DLT aims to increase trust and transparency of data, but this data could theoretically be falsified before being entered into the system.

Technology may make intentional diversion more difficult, but all technologies – not just document authentication or DLT – could in theory be circumvented with sufficient skill, time and resources. Thus, not every issue can be addressed solely through the addition of technology; counter-diversion requires a whole-of-system – or even whole-of-society – approach, within which technology is but one component. (This is discussed further in Section 3.)

In addition to exploring distinct stages of the transfer life cycle, workshop participants were also asked to reflect upon the different elements comprising counter-diversion, drawing on the research conducted for the first phase of D-TECT. These elements are presented in Table 3.

Relevance of technologies for counter-diversion

Overall, survey and workshop participants considered **all 14 technologies to have potential relevance in helping SALW counter-diversion**. Participants did not consider any of the technology

Table 3: Elements of counter-diversion[17]

Element	Description
Prevention	Prevention takes place before diversion effectively happens and involves interventions and measures to prevent actors from diverting conventional weapons and related components from their authorised end user or end use.
Detection	Detection takes place during the diversion efforts and involves measures and interventions to detect when diversion is happening and measures or interventions to prevent the diversion.
Identification	Identification deals with actual cases of diversion; thus, it occurs after diversion has taken place and involves interventions and measures to identify such cases and to analyse where the diversion effectively happened with a view to supporting and optimising future diversion-prevention efforts and initiatives.

options identified in phase 1 of Project D-TECT as having a potential negative impact on counter-diversion. Participants generally assessed technologies as providing either a moderate improvement in comparison to current capability or practices or, in some cases, negligible or no difference in comparison to current capability or practices. Individual responses also show that some respondents felt some technologies could potentially provide significant improvement in comparison to current capability or practices.

More specifically, **the types of technologies participants identified as most relevant tended to differ depending on the life cycle stage**. For example, at the transfer stage, the highest rated technologies were document authentication, e-seals, GNSS and mobile tracking, and RFID. These scores reflect transfer-specific considerations relating to SALW, namely relating to the ability to identify items and false documentation and the ability to prevent the rerouting or theft of SALW. At the post-delivery stage, however, while RFID, e-seals, and GNSS and mobile tracking were also highly rated, document authentication was not and was instead replaced by sensors and chemical encoding. These scores reflect a possible response to known risks of diversion from stockpiles or during active use due to inadequate security of infrastructure, theft, loss through negligence or capture. Workshop discussions on these two stages also pointed to the fact that technology relevant to counter-diversion within these stages should be applied as early as possible in the SALW life cycle. Overall, this demonstrates a need to **consider whether and how technologies applied in one stage can provide benefits at other stages in the life cycle – even if these are not necessarily apparent at that specific stage**.

The overlap in relevant technologies between stages partly reflects the slightly artificial divide between the different stages as conceptualised for this research. This is compounded by the fact that **some technologies have multiple areas of relevance and purposes** (as shown in Table 1). For example, there is the potential for additional marking information to be present on SALW in the form of RFID tags. However, RFID tags could equally aid with the inventory of individual SALW in stockpiles, as well as in tracking shipments by being placed on packaging (see the box on the next page). Therefore, the various figures below on technology relevance should be read alongside the qualitative findings emerging from the workshop discussions, which provide a broader contextual understanding.

Deep dive: Reflections from workshop participants on RFIDs

RFIDs scored highly in terms of potential impact; indeed, this is a technology with which most participants appeared to be familiar, in addition to it being a technology whose use has been proven given that it is already used to aid with logistics, particularly in the civilian sector. Within the context of SALW counter-diversion, the ability of RFIDs to aid with physical security and stockpile management was discussed in depth because they offer the possibility to increase the frequency of checks and audits by scanning multiple RFID tags at once and not requiring the need for physical inspection.

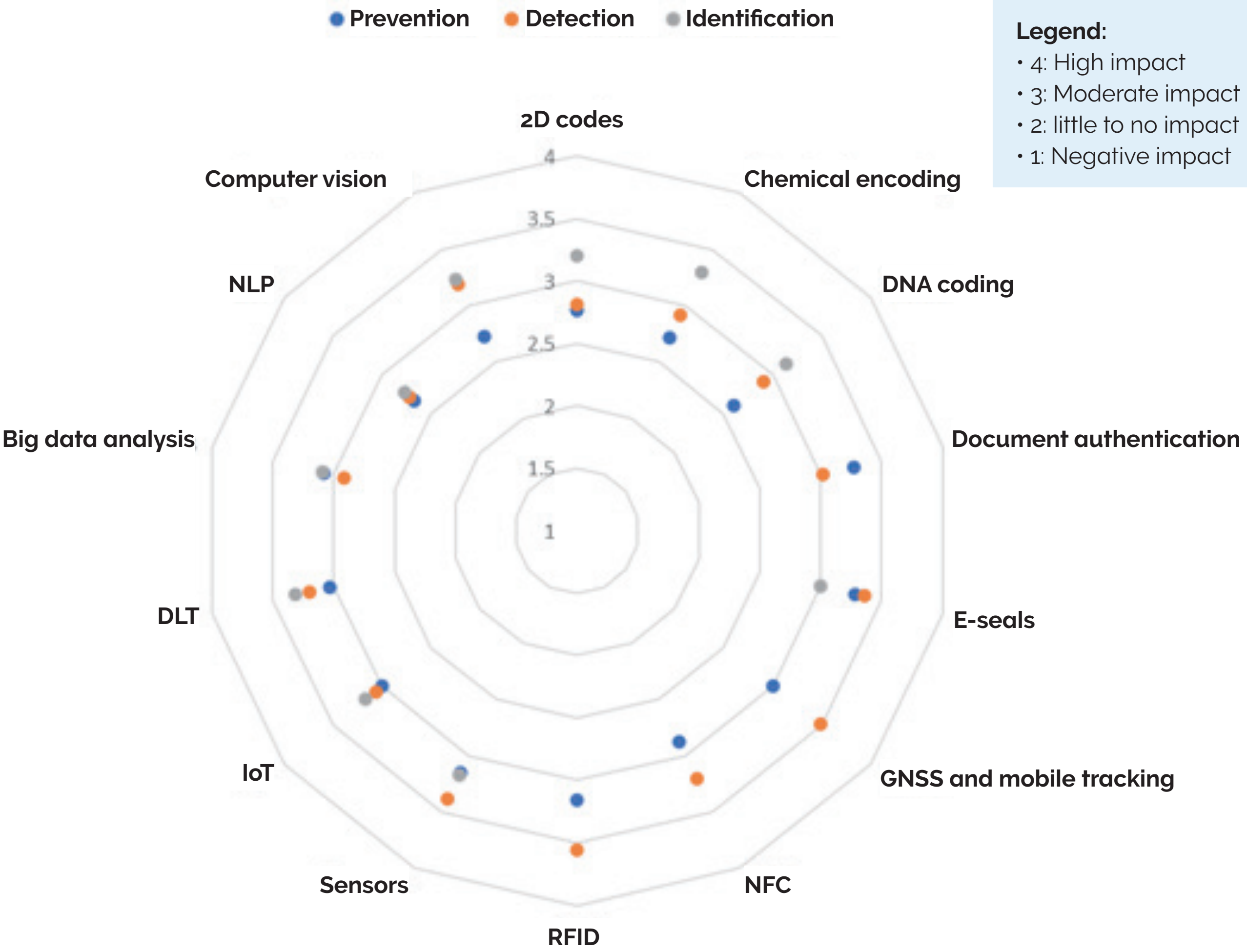
While acknowledging their possible impact, participants also raised the possibility for human errors or biases that could emerge from the use of RFIDs, such as over-trust in technology. For example, use of RFIDs to facilitate stockpile checks can lead to fewer physical inspections. Results from the scans can feed into the assumption that all SALW are in the storage facility, but issues and errors could still occur, and physical inspection and verification would still be needed periodically to conduct holistic checks.

The relevance of technology also varied according to the specific element of counter-diversion (i.e., prevention, detection or identification). For example, in the transfer stage, participants identified technologies that provide additional, item-level identification (e.g., 2D codes, chemical encoding and DNA coding) as being better suited to the identification of SALW. In contrast, they identified technologies that provide tracking and tracing capabilities (e.g., RFID, NFC, and GNSS and mobile tracking) as being better suited to aiding detection over prevention. These differences are illustrated in Figure 3, which shows the differentiation in impact between the different counter-diversion elements.

Participants determined that most of the assessed technologies are better suited to detecting diversion as it occurs or once it has occurred, rather than preventing diversion. The perceived effectiveness in aiding prevention, detection or identification also varied. For example, the assessed impact of technologies such as IoT, NLP, DLT or sensors is closely clustered, indicating that there may be minimal differences in the perceived impact of the technologies across the elements of counter-diversion. However, there is a greater difference in the assessed impacts of chemical encoding, RFID, GNSS and mobile tracking, and NFC, indicating that these may be more suited to taking a specific role in aiding with counter-diversion.

These results demonstrate the necessity of careful consideration when selecting a technology to ensure that it will adequately fulfil the intended purpose. Additionally, they also demonstrate where technology might provide added value compared to "traditional" or non-technological approaches to countering the diversion of SALW. Such approaches tend to focus on preventing diversion, whereas technologies generally appear to be more suitable for *detecting* and *identifying* diversion, hence demonstrating a complementarity between approaches. This data also demonstrates that overall scores on a technology's potential impact on counter-diversion do not differ significantly between less complex technologies (e.g., 2D codes, chemical encoding and document authentication) and more complex technologies (e.g., IoT, DLT and some of the AI-related technologies; see Figure 2 above for a mapping of technologies according to their complexity). The box below provides a specific overview of findings on the AI technologies.

Figure 3: Impact of the technologies on the various elements of counter-diversion of SALW (all stages combined)[18]



Legend:
- 4: High impact
- 3: Moderate impact
- 2: little to no impact
- 1: Negative impact

Deep dive: Reflections from participants on AI technologies

AI technologies tended to be scored as having a slightly lower impact than other technologies. Despite these scores, participants showed a certain level of interest in AI technologies, particularly around their potential use in data-heavy processes that occur in the pre-export, transfer and post-delivery stages. Some participants noted that they could see the utility of AI technologies in helping to verify licence applications or helping private sector actors to conduct risk assessments, especially in areas faced with limited personnel or time-consuming tasks. An example provided from the transfer stage was of a pilot project within a private company to use AI to examine descriptions of items for export in order to aid with the large amounts of data that require checking at this stage. Although the pilot has shown some promising results, further work is required to improve the quality of source data and to reduce the high number of false positives (i.e., identifying more risks or issues than there were in reality).

▶

▶ Overall, **lower impact scores were considered to be, in part, due to unfamiliarity with AI technology, uncertainty as to how it could be applied, and a lack of trust regarding the potential for errors**. For example, participants were unsure as to how public sector actors could use AI technology. They also raised concerns about the accuracy of algorithms. Increased education and understanding of possible error rates compared to humans could therefore be useful, as well as specific examples of how this type of technology is or could be applied by a range of actors.

Errors can of course happen regardless of the type of technology used. Yet, the significance and impact of an error can vary depending on the technology. For example, an error in the data contained within a 2D code for an individual SALW or an issue preventing the scanning of a 2D code is of a different magnitude compared to an error made by an AI model that is intended to assess diversion risks for an international transfer of thousands of SALW. Broader questions for consideration emerged from this discussion:

- Is human error more acceptable than errors emerging from the use of an AI technology?
- To what extent are users willing to accept errors caused by technology versus those caused by humans?
- What thresholds would users accept for errors before these undermine a technology's potential impact or utility?

Barriers to technological adoption

In addition to examining the potential impact of technology, it is also important and necessary to understand what barriers to adoption each technology may face. To do so, survey respondents were asked to assess the extent to which each of the requirements outlined in the next box could pose a barrier to the successful implementation of counter-diversion technology, focusing on technology-specific barriers to implementation.

Potential barriers to the successful implementation of counter-diversion technology

- **Skill requirements**: Knowledge of the technology (how to implement it and how to use it) and the training accessible and available to gain these skills, as well as having reliable and trustworthy personnel.
- **Infrastructural requirements**: Availability of both the physical and virtual infrastructure needed to enable the technology to function, such as secure location, electricity, (security of) connectivity, etc.
- **Cost requirement**: Financial costs related to the development, acquisition and maintenance of the technology, its related enabling infrastructure and the personnel needed for the technology to function.
- **Regulatory requirements**: The need to have new or updated regulations or legislation in place to enable the use and implementation of the technology.
- **Ethical and social requirements**: Societal trust and acceptance of the technology to deliver as intended and ensure security of information, and trust between the partners involved in the use of the technology.

Overall, participants scored the 14 assessed technologies as being subject to small- to medium-sized barriers in their implementation. However, this assessment could vary depending on the different possible use cases, with particular nuances. Namely, the barriers faced by a technology were found to vary slightly depending on the counter-diversion stage. Table 4 shows the three technologies found to face the lowest barriers to implementation versus those with the highest barriers across the three stages. On the one hand, DNA coding was consistently found to face high barriers. This was perceived as being mainly related to the cost, infrastructural and skill requirements. High barriers were also noted at the pre-export stage related to regulatory and ethical and social requirements. On the other hand, document authentication and 2D codes were consistently found to face lower barriers to implementation.

More specifically, participants perceived **infrastructural and cost requirements as posing the highest barriers to the successful implementation of the technologies**. Ethical and social requirements were perceived as posing the lowest barriers. This finding was consistent across all three stages.

Yet, low barriers to implementation only show a partial picture of the potential of a technology. Selecting technology purely based on its potential for low barriers can be reductive (as discussed in the box on the next page). It is also necessary to consider suitability to address the issue at hand, combined with willingness to overcome barriers to implementation.

Table 4: Technologies assessed as facing the highest versus lowest barriers to implementation, by stage of counter-diversion[19]

Pre-export stage	
Highest barriers to implementation	**Lowest barriers to implementation**
GNSS and mobile tracking	2D codes
DNA coding	Document authenticationǂ
DLT	E-sealsǂ
Transfer stage	
Highest barriers to implementation	**Lowest barriers to implementation**
DNA coding	Document authentication
DLT	2D codes
Computer visionǂ	RFID
Chemical encodingǂ	
Post-delivery stage	
Highest barriers to implementation	**Lowest barriers to implementation**
DNA codingǂ	Document authentication
GNSS and mobile trackingǂ	E-seals
IoTǂ	2D codesǂ
Big data analysisǂ	NFCǂ

ǂ *These groups of technologies had the same total score for barriers to implementation within their respective stage and respective "category" (i.e., high barriers or low barriers).*

Deep dive: Reflections from workshop participants on 2D codes

2D codes is one of the least complex technologies. It was already well-known among the workshop participants. 2D codes could contain additional information other than that required by the International Tracing Instrument (ITI) and they can be applied at any stage in an international transfer. It was noted that this type of marking could be well-suited for states with lower capacity because the barriers to implementation are lower and equipment for marking 2D codes already exists and has been tested on SALW and other types of items.

However, questions were raised as to the value of adopting this seemingly high impact and low barrier technology for SALW. Participants questioned what information would need to be added to such marks that is not already available. For example, the type of information that could be useful to include (e.g., transfer data) would not be automatically reflected in a 2D code unless that information was updated in a wider database that could be queried by scanning the 2D codes. In a similar vein, the utility of such a technology would only be realised if there is a means to store and read the data from the codes and make it searchable across a range of entities and stakeholders.

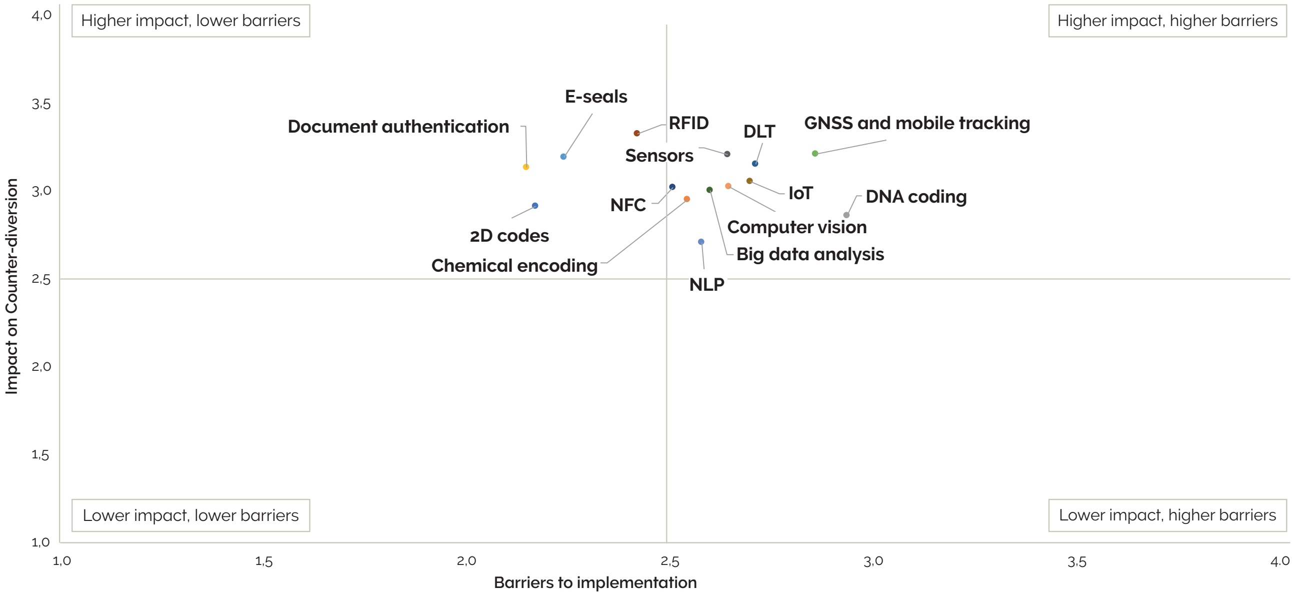
Moreover, the effectiveness of 2D codes to aid physical security and stockpile management and reduce time-consuming processes was not apparent to participants. Each SALW would still need to be individually scanned, not to mention the heightened potential for such marks to be rendered unreadable. Participants also noted that 2D marks could be intentionally removed, which could impede subsequent tracing of items. The importance of durability is illustrated by an account of an entity that used 2D codes printed on military-grade stickers as a way to affix marks on items that had none. These stickers were therefore added to individual items for identification purposes. However, use in the field showed limitations in the approach: stickers fell off items or became unreadable.

Assessing technologies' impact versus barriers

The survey data and workshop discussions enabled an examination of the trade-offs between perceived impact on counter-diversion versus perceived barriers to implementation. When scores for impact and barriers are examined together (see Figure 4), all technologies fall in the "high impact" quadrants, though with some facing higher barriers than others. **Technologies assessed as having a higher impact while facing lower barriers include document authentication, e-seals, RFIDs** and, to a lesser extent, 2D codes and NFC. Such a rating of these technologies may also reflect concerns with regards to risks and methods of SALW diversion, namely as regards document falsification (e.g., of transport documentation or end-user certificates) or the ability to mitigate or prevent loss, theft or illicit transfer of items. Conversely, the AI-related technologies and other more complex technologies such as DLT or IoT all feature in the upper right-hand quadrant.

Examining the trade-offs helps put into context the technologies assessed as potentially having a higher impact on counter-diversion. While Figure 4 provides the overall results – merging data across the three stages and diversion elements of counter-diversion – the clustering in the upper two quadrants was consistent even in disaggregated data. Within the disaggregated data, the main differences emerged within the stages or counter-diversion elements, where different technolo-

Figure 4: Mapping of technologies by impact versus barriers[20]



Legend: X-axis:
- 4: Insurmountable barrier
- 3: Medium barrier
- 2: Small barrier
- 1: Not a barrier

Y-axis:
- 4: High impact
- 3: Moderate impact
- 2: Little to no impact
- 1: Negative impact

gies were assessed as having a higher impact (see Figure 4). For example, in the transfer stage, while GNSS and mobile tracking was perceived by respondents as having a potentially high impact on counter-diversion, it has also been assessed as facing greater barriers than most technologies. One participant, for example, highlighted that this type of technology could make SALW shipments more trackable, with detrimental implications for privacy and national security.

This technology mapping reflects several of the elements discussed above: how familiarity with a technology, trust in its ability to perform as expected and knowing that it is used in the context of counter-diversion can have an impact on the perception of barriers to the implementation of a technology. Further considerations, such as the visibility and the deterrent effect of technology (as discussed in the box on this page), may also have played a role in shaping these results. Ultimately, as technology develops, improves and democratises and as changes also occur in the broader system including the arms trade, such an assessment may change – thus, this mapping should not be seen as static nor absolute.

Deep dive: Reflections from workshop participants on the impact of "visible" versus "invisible" technologies

The visibility – or lack thereof – of technology was discussed at length. The main point of reflection was the extent to which application of technology serves as a deterrent to diversion or reduces the attractiveness of diverting SALW. Two aspects of "visibility" were examined by participants.

On the one hand, visibility of a technology in terms of its physical presence was discussed. The impact on counter-diversion of the visibility of a technology appears to depend on the type of technology and the intended counter-diversion purpose (i.e., prevention, detection or identification). For example, 2D codes were noted as being visible, and therefore illicit actors would know to remove the marks. On the other hand, non-visible marks such as chemical encoding or DNA coding may be more resilient, in part due to their invisibility.[21] In other words, more covert markings could be beneficial to avoid counteraction by illicit actors.

On the other hand, visibility was also discussed in terms of the wider knowledge that technology is being used, and not just what is visible to the naked eye. A deterrent effect could be achieved by letting potential offenders know that technology has been applied, thereby openly advertising the elevated risks to these actors of their detection and identification. One workshop participant gave an example of this regarding a north-eastern African country, where visibly marked SALW were not used in crimes because users believed that their use could be traced back to them. This was not possible, due in part to the fact that data on ammunition was missing, but the perception nonetheless had an impact on SALW (mis)use.

Exploring technology combinations

While technologies were examined individually within the survey, they can be combined to leverage their respective strengths and overcome individual weaknesses. This is particularly relevant given that the survey data revealed that different technologies emerged as having a greater impact for certain elements of counter-diversion as well as for certain stages of the transfer process. Moreover, participants noted that it was highly improbable that only one type of technology could be applied across the SALW life cycle to effectively address all areas of risk.

As illustrated in Table 1, the technologies are highly diverse. For example, some are meant to be applied directly on SALW (e.g., chemical encoding), others on packaging (e.g., GNSS or mobile tracking), or to otherwise improve or strengthen the wider process (e.g., document authentication or DLT). **These different areas of application are complementary and therefore layering these technologies could have a compound effect on countering diversion of SALW.** This could be the case within a specific stage of the life cycle, as well as across the SALW life cycle. Certain technologies also need to be in place before others can be considered. For example, digital infrastructure would be needed to enable tracking and tracing technologies, which in turn would need to be in place to enable data-driven technologies such as DLT or AI capabilities.

Taking survey responses from the transfer stage and examining high-scoring technologies across subcomponents of diversion, patterns emerge as to how different technologies can complement each other. For instance, use of chemical encoding, RFID, sensors and big data analysis could help fulfil different purposes, such as provision of additional item-specific information, helping documentation-heavy processes, tracking and tracing items or their packaging, and helping increase the security of the goods along the way. Similarly, when looking across the life cycle, technologies that scored highly in terms of their overall relevance as well as specific relevance in helping to either prevent, detect or identify diversion (e.g., chemical encoding, RFID, document authentication, GNSS and mobile tracking, and DLT) could potentially provide a good combination aimed at addressing different needs.

These examples are purely illustrative. Specific combinations of technologies would differ based on the needs assessment, the ability of a technology to respond to this need and the specific context of implementation, in line with the D-TECT evaluation framework. Indeed, the context in which a technology is applied would influence the benefits or positive impact that a technology can have.

Section 3 - Systemic barriers to technology implementation and ways forward

This section first examines the main systemic barriers to implementing a technology for counter-diversion of SALW that emerged during the workshops. It then provides an overview of possible avenues that could be explored or undertaken to mitigate or overcome the barriers. It should be noted that the type and extent of each barrier differs depending on the stakeholder. While the barriers and the possible ways forward aim to capture a range of perspectives and issues, these cannot encompass all context-specific barriers and related ways forward. **Overall, the overarching theme that threads through many, if not all, of the barriers is that of trust – or its absence – and how to build or enable it**. Because trust is multifaceted, it can encapsulate trust in the technology, users, decision-makers or system to act in a reliable and secure manner.[22] This issue is also linked to a more general lack of knowledge or awareness of technologies and their potential uses, an element which the options to overcome the barriers also seek to address.

Systemic barriers to technology adoption

The workshop participants recognised that technology may be a helpful tool to aid counter-diversion efforts. Reasons to use technology are varied and include:

- improving knowledge of unknowns through better use of data;
- complementing existing approaches to risk mitigation;
- overcoming space and time constraints (e.g., the time-consuming and physical nature of post-shipment verification); and
- enabling sufficient data and information to conduct forensic analysis.

Some participants also expressed the sentiment that, if technology was not adopted in certain instances, then the problems will persist, especially regarding traceability and transparency. Similarly, barriers to technology adoption exist and were discussed at length, given how they can be or can seem to be prohibitive to the adoption of technology (as described in Section 2). In addition, the workshops focused particularly on the system-wide barriers or limitations to the implementation of technology.

Fragmentation among the multiple actors involved in SALW

During the SALW life cycle, a range of actors are involved, including exporting and importing states, their national authorities (including border control and custom authorities), as well as the manufacturing entities and industry (as regards SALW), private sector (as regards technologies), users of SALW and those involve in their disposal, in addition to different types of intermediaries such as freight forwarders and brokers.[23] These different actors may not always operate in a cohesive and unified manner, leading to a fragmented landscape. This can have an impact on technology implementation. For example, some actors could veto or otherwise hamper the use of (certain) technologies, which can have a domino effect beyond their specific remit. Further, the lack of coordination can lead to siloed collection and use of data. This landscape can also make it difficult to have conversations as to whether and how costs could or should be shared among different actors. Currently, there are no requirements to use technology, although there may be requirements to accept technologies applied by state and non-state actors across the life cycle. This can open several questions, for example, as to who is responsible for the various costs in such circumstances, or the additional workforce, if required.

Practicalities of technology development and adoption

Technology first needs to be developed or acquired. Some types of technologies could be developed in-house (e.g., by skilled personnel or specific entities or departments), whereas others may require working with the private sector or transferring technology from a trusted partner. Each of these approaches has short-term advantages and drawbacks, as well as longer-term implications. On the one hand, this brings to the fore questions on the willingness of states to provide technology to other states, or on finding and selecting an appropriate vendor and thus about the standards of technology developed by a non-state actor. On the other hand, technology should be considered as a long-term investment, as the broader system in which it would operate would need to adapt and change around the technology. The difficulty of changing existing systems can be a factor that prevents the adoption of technology, despite an understanding that technology can help. An example of one such practical issue was illustrated by an interviewee, who described a situation where a licensed digital technology had been provided to licensing officers. After this technology had been employed for a certain time, there came the point where the technology's licence required renewal. To avoid this, the unit ended up internally developing its own database-management system.[24]

Lack of infrastructure surrounding the technology

Technology requires a number of elements to be in place in order to for it to correctly undertake the function it is meant to fulfil; indeed, a lack of these elements could have an impact on the ability of technology to act as a deterrent beyond just the technology's capabilities in themselves. These elements include:

- lack of sufficiently robust physical structures;
- lack of a digital infrastructure, such as a digital database management system; and
- weak or non-existent political and legal frameworks and good governance that would prevent the enforcement of consequences in cases where diversion has been uncovered.

Cost of technology

The (high) cost of technology is an often-cited reason for a reluctance to adopt technology. It should be noted that costs may fluctuate, and, for certain technologies, may reduce over time, for example, if they become more mainstream, with a wider market. Yet, it is not just the cost of a technology purchase that needs to be factored in, but also the cost of training the personnel meant to work with it, the cost of maintenance or replacement of elements or the whole solution, and, in some cases, the cost of modernising systems, training and infrastructure in order to enable the most recent technologies. Differences in the resource levels of states and private sector actors can hamper an equal adoption. Participants noted that these costs can be particularly off-putting for public sector actors. Additional factors compounding the cost of technology can also include lack of or insufficient resources of entities interested in technology adoption, as well as minimal international assistance, which may not allow funds to be allocated for technology use and training in technology.

National security considerations

There are concerns that use of technology could, on the one hand, lead to exposure of weaknesses that may have repercussions for broader national security and, on the other hand, cause physical damage, such as by triggering explosions. Regarding the first point, these concerns mainly pertain to digital and connected technologies (e.g., DLT, IoT, AI technologies), as well as technologies that have GPS functions or an electromagnetic signature (e.g., GNSS and mobile tracking, RFID, e-seals). Issues raised include fears that software containing data on SALW could be compromised, such as through cyberattacks or the ability for SALW to be tracked and traced by harmful actors. This concern is particularly acute within the post-delivery stage, when SALW are stockpiled or during their active use. The second set of concerns relates to fears that the use of certain frequency-emitting technologies could negatively interact with ammunition or other types of weapon systems (including potential accidental triggering), primarily during stockpiling, but also during their deployment. This latter issue is notably addressed in the International Ammunition Technical Guidelines (IATG) 5.60 on hazards of electromagnetic radiation, which notes that radio frequencies can be "potentially hazardous when used in close proximity to explosives that have an installed electrical means of initiation".[25]

Lack of knowledgeable personnel

Humans remain central to the use of technology. Participants stressed that the notion that technology can replace humans in counter-diversion is incorrect and an assumption to be avoided. Technology cannot fully replace the need for skilled individuals or essential procedures: human input, intervention and judgement will always be indispensable. However, a lack of trained and knowledgeable individuals can have a negative impact on the implementation and management of the technologies, impeding their effective use and ability to achieve the desired end-result. Thus, the need to ensure that personnel have the appropriate training and skillset and can be retained in the long-term can act as a barrier to technology adoption. It should, nonetheless, be noted that the type and extent of training and skills may differ and be more or less extensive depending on the technology; this would also then be reflected in the knowledge, training and skills required from individuals. This point is also linked to a broader one on the overall limited knowledge and awareness of available technology and its potential uses by the multiple actors involved in the life cycle of SALW.

Need for data and data management

Participants discussed at length the centrality of data for countering diversion, including data collection, record-keeping and background data systems. The need for a robust data and information management infrastructure was noted; indeed, many of the technologies depend upon the existence of data systems to be used meaningfully or even to operate. However, issues raised by participants highlighted the types of barriers which exist, such as approaches to robust data collection and management, potential sensitivities and challenges as to where and how the data is stored, as well as open questions regarding data sovereignty.

Overcoming systemic barriers

Participants provided ideas and suggestions to mitigate and overcome the systemic barriers. An initial, non-exhaustive set of options and avenues through which these could be achieved at the national, regional or international levels is offered below. It is important to stress that the ability to mitigate or overcome barriers can differ depending on the stakeholders involved, the type of barrier, the extent to which technology needs to be adopted, and the willingness to overcome the barriers. Even so, it is hoped that demonstrating that there are options available to overcome the overarching barriers can help to advance discussions and expand options for technology adoption in the context of counter-diversion efforts. Moreover, many of these actions can be undertaken with a broader focus on counter-diversion. Indeed, some of the actions are not only focused on the goal of technology adoption, nor are they necessarily always specific to SALW. This lends such actions to being well placed to be addressed through international treaties which have broader remits, such as the ATT.

Collaboration and inter-agency cooperation

National and international collaboration and cooperation between stakeholders are of particular importance in a multi-stakeholder environment, notably as regards inter-agency coordination, cooperation and information-sharing at national and international levels to counter diversion.[26]

- Gather and share inputs and suggestions on technological innovation; practical technological adoption; how specific technologies could work in practice; the advantages, drawbacks and impact on different stakeholders as well as on the system; and good practices and lessons learned. This could be achieved by:
  - creating a data-sharing platform, such as an online tool;
  - holding multi-stakeholder dialogues or workshops; or
  - creating guidance material.

  These avenues could be led by states within existing forums and multilateral instruments at the international level. For example, relevant topics could be included within the scope of the ATT's sub-working group on current and emerging implementation issues, in the ATT's Diversion Information Exchange Forum (DIEF), or in the scope of a possible technical expert group for the PoA/International Tracing Instrument (ITI). Initiatives could also be pursued under regional SALW-control instruments and regional cooperation frameworks.

- Enhance collaboration and cooperation between different relevant actors. This could be achieved by:
  - continuing consultations and multi-stakeholder dialogues at the national and international levels, including with government agencies (e.g., licensing authorities, customs agencies, intelligence organisations) and the private sector (e.g., producers, shipping companies, etc.) to improve or establish day-to-day communication channels and relationships;
  - setting-up partnerships through which to seek ways to offset costs or examine possibilities for economies of scale or subsidies, for example, through a focus on technologies that could also be applied for other purposes or within other spheres; alternatively, through an examination of whether other actors would be willing to develop and adopt similar technologies, in which case, cost-sharing could be considered.

Evidence and knowledge-building

In-depth knowledge and understanding of the various technologies can vary, including regarding the extent to which they might be relevant and how they could be applied; this could be mitigated by increasing the knowledge base.

- Foster common understanding on the different types of technologies aimed at countering diversion. This could be achieved by:
  - developing a common lexicon of technical terms, which could cover what a technology means and what it can and cannot provide in terms of information, to increase understanding and trust in the various technologies;
  - developing a platform for the voluntary sharing of the results of monitoring and evaluating the use of technology to counter diversion, at the national, regional and international levels; such a platform can encourage accountability and transparency, providing valuable

insights and evidence to inform decision-making and improving the effectiveness of counter-diversion efforts.

- Conduct studies and assessments on the potential and actual utility of different technologies for countering diversion throughout the life cycle of SALW (as well as conventional arms and ammunition more broadly). Topics discussed among the participants include:
  - conducting context-specific case studies and assessments on the technologies at the local, national or regional levels to examine how they work, the benefits they offer, and the drawbacks and costs involved in their implementation, use and maintenance;
  - examining the extent to which SALW becomes less attractive for diversion as a result of technology use;[27]
  - ensuring continued research and development on technologies to ensure compliance and ensure that any innovations are duly noted;
  - assessing the cost of non-adoption of technology against the cost of technology adoption or the cost of technology implementation – this could be undertaken by considering issues such as the size of the problem versus the cost of the solution, as well as the potential benefits versus the cost of the solution;[28]
  - undertaking specific testing and piloting of specific technologies by states, industry and technical implementers in order to determine context-specific practical applicability of technologies and determine technical needs;[29] this could also be undertaken at the regional level.

Institutional capacity-building and individual training

Successful implementation of technology relies not just on the technology itself, but also on the surrounding infrastructure, which includes people and processes. Thus, learning and development are key areas of focus to enable and facilitate change management.

- Offer long-term incentives, funding and training to states and the private sector to enable the necessary supporting infrastructure. This could focus on increasing national and regional capacities regarding legal, regulatory and policy frameworks to enhance effective governance and enforcement of regulations, as well as on people and infrastructure (the latter of which is discussed further below). This could be achieved by using existing international and regional cooperation and assistance frameworks, such as the ATT's Voluntary Trust Fund. There is also potential for creating new international and regional cooperation and assistance frameworks to support the use of technology for countering diversion.

- Implement policies that focus on improving the retention levels of trained personnel and their knowledge. This could be achieved by putting in place specific knowledge-management policies, whereby individuals leaving a department or service ensure that their knowledge is transmitted.

- Enhance technology adoption and trust in technology use through long-term educational and capacity-building initiatives that focus on skills development and specialised training among the workforce, at the individual level. These initiatives should ideally be long-term, to last from several months to several years. This could be achieved through train-the-trainer initiatives.

Physical, regulatory and digital infrastructure

In addition to people and processes, technology requires an adequate physical and digital infrastructure to function, in addition to appropriate regulatory frameworks.

- Ensure that core elements and a strategy for a digital infrastructure are in place, such as power backups and IT infrastructure, including the hardware (e.g., servers), software (e.g., cybersecurity) and human expertise. This could be achieved by:
  - implementing background data-management systems to capture relevant data – this should include agreement on how the data within these management systems and databases is managed and by whom;
  - applying and following strict data-management regulations to abide by ethical and legal considerations – this includes applying cybersecurity principles to prevent cyber incidents and data leaking;
  - improving the cybersecurity of digital systems, for example, by ensuring proper access control, implementing proper cybersecurity protocols, regularly updating systems and undertaking maintenance; additionally, focusing on training personnel and minimising insider risk, by drawing upon existing sources of knowledge and research;
  - implementing tools to monitor the performance, availability and security of technologies, in addition to tools to configure and manage IT resources.

- Establish or strengthen national or even regional archival processes, such as through backup systems whether digital (e.g., cloud infrastructure) or physical, to overcome the risk that use of information and communications technologies and digital platforms weakens archival processes. Archival material is important, particularly when it comes to the "identification" element of counter-diversion. This could be achieved by harmonising different information-collection and data-sharing systems to ensure interoperability and aid with collaboration and cooperation.

- Utilise or implement robust frameworks on the adoption and use of technologies, to also ensure that these can help guide users and frame the use of technology, as well as to ensure enforcement and other actions possible to act upon the data. This could be achieved by:
  - implementing existing guidelines (e.g., IATG 5.60) that provide procedures as to the use of such devices in ammunition-storage areas as well as for tracking of weapons or their packaging, including on how to apply passive and active RFIDs; additionally, implementation of the MOSAIC guidelines on stockpile management, specifically regarding the use of technology for weapons accounting, could also be considered;[30]
  - putting in place systems – whether technical, human or both – that examine the collected data for anomalies or other issues and can identify instances of diversion.

Section 4 - Conclusion

This paper presents an overview of whether and how technology could be implemented to help counter the diversion of small arms and light weapons, including an assessment of which types of technologies might be better suited to the task. Overall, **the 14 technology types identified in the first phase of Project D-TECT, broadly speaking, are all potentially relevant to counter-diversion efforts**. Some technologies are more suitable to aiding detection than to prevention and identification.

Nonetheless, **all technologies face barriers to their implementation, although the nature and extent of these barriers is context specific**. There are also overarching structural barriers that may impede adoption of technology more generally, in addition to technology-specific barriers. These include:

- arms control infrastructure;
- the nature of the international arms trade, which features a large number of different types of actors; and
- national security considerations that may emerge due to the use of technology.

The paper, however, does not provide a definitive answer as to what specific technology, or combination of technologies, should be implemented or prioritised to counter the diversion of SALW. **This is because the most appropriate technology will vary depending on the context and on the needs behind its implementation.** In other words, it is not possible to provide an answer to the question of "which is the most suitable technology" because the technology and how it is applied is not a one-size-fits-all solution.

The approach taken to assess selected technologies was a proof-of-concept. To move beyond illustrative findings, **there would be merit in replicating such an exercise in a specific country or at a regional level** to enable the assessment of the technologies against a specific need and within a specific context. Indeed, the effectiveness of a technology can vary according to its context of implementation, which is one of the three steps within the framework developed to identify and assess technologies to counter the diversion of conventional weapons.

There are systemic barriers that can hamper the implementation and use of technology. Yet, **these barriers should not be seen as precluding the use of technology**. The paper provides a non-exhaustive overview of possible options that could be undertaken to overcome or mitigate these barriers, including:

- strengthening international and regional collaboration and inter-agency cooperation;
- building up the evidence and knowledge base;
- reinforcing or setting up appropriate physical, regulatory and digital infrastructure; and
- undertaking institutional capacity-building and individual training.

Some of the options proposed could also build on existing international and regional initiatives and instruments, such as the PoA/ITI or the ATT. Moreover, the use of appropriate technology represents a common challenge for states as well as for private sector actors, thus requiring a cooperative approach to develop appropriate options as well as standards of use.

Technology can act as a supportive tool or as a force multiplier to counter-diversion efforts. As shown by the barriers, options and avenues for action, its successful application nonetheless relies on oversight, on an enabling environment, on enforcement of frameworks, instruments and processes, as well as on broader political will. **These elements are the "building blocks" that are required to be in place to enable implementation of technology to aid counter-diversion**. These "building blocks" are also relevant to counter-diversion efforts more broadly – and not just focused on paving the path to technology use.

Ultimately, the application of technology to counter diversion should be an ongoing conversation, as both diversion and technology evolve, change, adapt and advance.

Endnotes

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7. Cops, D. (forthcoming), *Countering the diversion of components of conventional weapons. An assessment of potential technological solutions*, Flemish Peace Institute.
8. Some minor changes were made to the technologies assessed as part of the research for this second phase compared to the longlist from the first phase. Specifically, Physically Unclonable Functions (PUFs) were not included in the analysis because of its immaturity, while the broad category of "artificial intelligence (AI)" was disaggregated into three specific types of technologies to increase granularity. The food-for-thought paper from the first phase provides a detailed description of each of these technologies, as well as their current areas of application and where and for what purposes they could be applied to SALW or CWC. See Grand-Clément, S. & Cops, D. (2023), *Technologies to counter the diversion of small arms and light weapons, and components of conventional weapons*, Brussels: Flemish Peace Institute, https://unidir.org/publication/technologies-to-counter-the-diversion-of-small-arms-and-light-weapons-and-components-of-conventional-weapons-2/, pp. 9–17.
9. Popper, S. W. et al. (2013), *Strategic issues facing transportation, vol. 3, Expediting future technologies for enhancing transportation system performance*, Washington, DC: National Academies Press, https://nap.nationalacademies.org/read/22448/chapter/1.
10. Step 5 is considered to be a political decision-making process and is thus outside the scope of this research project.
11. With a view to strengthen participants' understanding of the selected technologies and to increase the reliability and validity of their responses, they were all provided with a guidance document describing the various technologies, the preconditions for their implementation, use cases and their potential relevance in counter-diversion efforts. In addition, a short online briefing was offered to all participants in which the technologies were presented and room for questions was foreseen.
12. For the first two life cycle stages, the workshops discussed both SALW and CWC (although the surveys examined these two types of items separately). For the post-delivery stage, separate workshops were held for SALW and CWC. The fourth workshop, on the post-delivery stage for CWC, is not reflected in the table since it was not about SALW.
13. Note that not all survey respondents were able to attend the workshops, and not all workshop participants completed the survey.
14. Martinez, M. et al. (2021), *Diversion Analysis Framework (Arms Trade Treaty Issue Brief 3)*, Geneva: UNIDIR, Conflict Armament Research, and Stimson Center, https://unidir.org/publication/arms-trade-treaty-issue-brief-3-diversion-analysis-framework/.
15. Conflict Armament Research (2018), Typology of diversion, *Diversion Digest*, 1, pp. 8–14, https://www.conflictarm.com/wp-content/uploads/2018/08/diversion-digest-01.pdf; Interview respondent 1 (UN sanctions expert), 11 September 2022; Interview respondent 2 (UN sanctions expert), 10 November 2022; Interview respondent 3 (international NGO), 17 November 2022; Interview respondent 4 (UN sanctions expert), 24 November 2022); Interview respondent 6 (international NGO), 28 November 2022; Interview respondent 17 (SALW counter-diversion practitioner), 14 December 2023.
16. Conflict Armament Research (2018); Cîrlig, C.-C. (2015), *Illicit small arms and light weapons: International and EU action*, Brussels: European Parliamentary Research Service, https://www.europarl.europa.eu/RegData/etudes/IDAN/2015/565869/EPRS_IDA(2015)565869_EN.pdf; Stohl, R., Dick, S. & Fletcher, R. (2021), Diversion and the Arms Trade Treaty: Identifying good practice and opportunities for progress, Washington, DC: Stimson Center, https://www.jstor.org/stable/resrep30825; Interview respondent 3 (international NGO), 17 November 2022; Interview respondent 4 (UN sanctions expert), 24 November 2022; Interview respondent 10 (international organisation), 10 January 2023.
17. Grand-Clément & Cops (2023), p. 7.
18. The visual shows the aggregate findings across the three stages of counter-diversion. The identification stage was not scored for document authentication, GNSS and mobile tracking, NFC, or RFID, based on analysis by the project team that suggested that this particular stage would be less relevant for these technologies and scoring would be redundant. Respondents were asked to assess whether the technologies would have a negative impact ("reduction in capability or negative impact in comparison to current practices"), little to no impact ("negligible or no difference in comparison to current capability or practices"), moderate impact ("moderate improvement in comparison to current capability or practices") or high impact ("significant improvement in comparison to current capability or practices").
19. For each technology, participants were asked to assess the extent to which these barriers were not a barrier ("the barriers would have no effect on the successful implementation of the technology"), a small barrier ("the barriers can be dealt with relatively easily"), a medium-sized barrier ("the barriers would be difficult or challenging to carry out"), or an insurmountable barrier ("the barriers would require action that might not be possible or practicable") for successful implementation.
20. The figure shows data aggregated across all three stages and all three elements of counter-diversion.
21. It should, however, be noted that invisibility is only one such factor here; indeed, unlike 2D codes marked on items directly, removal of chemical encoding or DNA coding would entail destruction of the SALW.

22. For a more in-depth overview on this point in relation to technology, as well as on other attributes perceived as being important, see Grand-Clément & Cops (2023), p. 20.
23. A comprehensive overview of industry and other private sector actors is provided in Mensah, A., Perkins, R. & Fletcher, R. (2023), *The Arms Trade Treaty: The role of industry and other private sector actors in efforts to counter the diversion of conventional arms* (Arms Trade Treaty Issue Brief 4), Geneva: UNIDIR, Conflict Armament Research, and Stimson Centre, https://unidir.org/publication/the-role-of-industry-and-other-private-sector-actors-in-efforts-to-counter-the-diversion-of-conventional-arms-att-issue-brief-4/.
24. Interview respondent 17 (SALW counter-diversion practitioner), 14 December 2023.
25. IATG 5.60 includes devices such as "mobile telephones, wireless communication links to high-powered transmitters for voice communication, electronic data transmission, asset tracking and radar" as frequency-emitting devices. See UN SaferGuard (2021), *International Ammunition Technical Guidelines: Hazards of electro-magnetic radiation* (IATG 5.60), New York: UN Office for Disarmament Affairs, https://data.unsaferguard.org/iatg/en/IATG-05.60-Hazards-electromagnetic-radiation-IATG-V.3.pdf, p. v.
26. Holtom, P. (2024), *The Role of interagency cooperation in the effective implementation of Arms Trade Treaty provisions: Brainstorming workshop summary,* Geneva: UNIDIR, Conflict Armament Research and Stimson Center, https://unidir.org/publication/the-role-of-interagency-cooperation-in-the-effective-implementation-of-arms-trade-treaty-provisions-brainstorming-workshop-summary/.
27. One example mentioned in a workshop was examining the cost differential between SALW on which tracking and tracing technology is known to have been applied, and those which do not have such technology (including assumed knowledge). If untraceable items become more expensive, then that is one way to identify the impact of technology.
28. For example, for technologies that are placed on items or their packaging, the cost of relevant technology may increase as the number of items increases. This can help improve understanding as to the amount of funds that could be put towards technology implementation, but also to help understand whether the benefits would outweigh costs.
29. For example, this could build on work conducted jointly by Conflict Armament Research (CAR) and TTE-Europe GmbH (TTE), which tested the use of RFIDs to identify individual weapons. To address concerns that RFIDs could have an impact on military operations by rendering SALW "visible" to adversaries, CAR developed a dual-tagging approach whereby an overt RFID could continue to be used for stockpile management, and a covert RFID could be used when in active use. See Conflict Armament Research and TTE-Europe (2021), *Field forensic firearm exploitation: Developing RFID solutions in support of stockpile management and post-diversion tracing,* Gentbrugge: Conflict Armament Research, https://www.conflictarm.com/technical/developing-rfid-solutions-in-support-of-stockpile-management-and-postdiversion-tracing/.
30. United Nations (2018), *Modular Small-Arms-Control Implementation Compendium (MOSAIC) – Stockpile management: Weapons*, New York: United Nations, https://front.un-arm.org/wp-content/uploads/2019/05/MOSAIC-05.20-2012EV1.0.pdf

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Flemish Peace Institute

The Flemish Peace Institute was established in 2004 as a para-parliamentary institution within the Flemish Parliament. It provides thorough analyses, informs and organizes the public debate and promotes peace and the prevention of violence.

Project D-TECT

Countering the **D**iversion of arms using **TEC**hnology **T**ools (D-TECT) is a joint project by the Flemish Peace Institute (FPI) and the United Nations Institute for Disarmament Research (UNIDIR). The aim of Project D-TECT is to develop and test an approach to identifying and assessing the utility and feasibility of using specific technologies that could be used to support or strengthen existing initiatives aimed at detecting, preventing, and mitigating the diversion of conventional weapons. Project D-TECT consists of two consecutive phases. The first, phase was to identify existing technologies that could be suited to countering the diversion of conventional weapon systems and develop a framework that makes it possible to identify and assess technologies used to counter diversion. The second phase is to assess, refine, and validate the list of identified technologies in relation to specific types of conventional weapon systems.

This current paper is a product of the second phase of the research. It focuses on examining the extent to which different technologies could help counter the diversion of small arms and light weapons and the barriers to their implementation.

D-TECT

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