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The Nexus between Strategic Trade Controls and Safeguards: State of Play and Current Challenges

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Abstract:

Practitioners working in the fields of international nuclear safeguards and export controls often conduct their research, development and implementation activities in isolation from each other. However, the two domains are inextricably linked. Both nuclear safeguards and export controls have been largely shaped by the same external factors and they are pervaded by shared goals, i.e. strengthening international security and ensuring that nuclear materials, equipment, facilities and technologies are not used for illegitimate purposes and/or by unauthorised users. Furthermore, they (at least partially) seek relevant information from common sources – export declarations related to Annex II of the Model Additional Protocol for safeguards, the Nuclear Suppliers Group Trigger List for export controls, as well as the description of the nuclear fuel cycle-related activities listed in AP Annex I. Given the mutually reinforcing role of both mechanisms, this paper aims to offer a state-of-the-art account on ways in which export control and safeguards verification processes, activities, and data can support one another. Additionally, the authors will provide an insight into current research challenges, such as entity resolution and dataset cross-matching, associated with utilizing relevant datasets. While looking at these challenges from a research angle, the identified issues have a bearing on the work of State authorities (be it nuclear regulators, export licensing or customs authorities) and the International Atomic Energy Agency's role for effective safeguards implementation.

1. Introduction

1.1 The role of export controls and international safeguards for non-proliferation and international security

Dual-use export controls, also known as dual-use trade controls, are an instrument for monitoring the trade of highly sensitive items including systems, equipment, components, and materials as well as software, technical data and knowledge that can be used for both civilian and military applications.[1] Export controls are required by UN Security Council Resolution (UNSCR) 1540 [1] and aim to prevent the proliferation of Weapons of Mass Destruction (WMD) including their means of delivery (e.g. missiles and drones) and, other technologies defined in export control lists as having a dual-use potential that can harm the international or national security and regional stability. Several dual-use items are associated with conventional military items listed under military lists and governed by arms trade controls.

[1] Trade controls of dual-use items is an increasingly used term as it better captures the multiple role of modern export control systems to monitor exports but also R&D processes, brokering, transit, transshipment and re-export od sensitive goods, depending on the national legislation.

This paper focuses on the nuclear export control aspects aimed at curbing the proliferation of nuclear items be it in tangible form (e.g. nuclear equipment, material, components) or intangible (e.g. nuclear technology/know-how, software and technical assistance). Export controls are defined and administered by States usually in accordance with control lists and best practices agreed upon in the framework of non-legally binding multilateral arrangements, the so-called international export control regimes, which have a strong participation[2] and also external adherents, however not a fully global membership. Moreover, there is no international entity overseeing the national implementation of export controls by States, beyond the work done by 1540 Committee to collect information on the implementation of the UNSCR 1540 requirements.[3]

International safeguards are a set of technical measures applied to nuclear material and activities that enable the IAEA to draw safeguards conclusions (i.e. verify that nuclear material and activities remain in peaceful purposes). Safeguards agreements, such as a Comprehensive Safeguards Agreement (CSA) with or without an Additional Protocol (AP), between the IAEA and a State provide the IAEA with the legal authority to implement these safeguards measures. The IAEA may also conclude such agreements with international entities representing a number of States most notably under the EURATOM safeguards agreement with the EU.

The IAEA is responsible for independently verifying the correctness and completeness of a State's declared nuclear material and nuclear-related activities and uses a variety of methods for collecting and analysing information, including:

- Declared information from the State, or data that is transferred to IAEA remotely from nuclear facilities;
- Information collected during in-field safeguards activities (inspections and complementary access visits) – including physical samples, nuclear material measurements and results from checking containment and surveillance technologies; and
- Information from the open-source, third parties, and satellite imagery.

Safeguards and export controls constitute integral components of the nuclear non-proliferation regime with the former conceived to ensure the peaceful application of nuclear technologies and the latter to prevent the misuse of sensitive dual-use items. Each of these instruments involves other functions, but the two intersect at points of proliferation risk within the Nuclear Fuel Cycle (NFC) [2], [3].

This paper intends to highlight the mutually reinforcing and -at times complementary- role of safeguards and export controls for nuclear non-proliferation by discussing examples where export control and safeguards processes, activities, and data can support one another.

1.2 Historic evolution and recent trends for safeguards and export control implementation

Nuclear safeguards and export controls are based on the same principles and legal obligations stipulated in the Non-Proliferation Treaty (NPT). Safeguards measures in particular are mentioned explicitly as a prerequisite for the provision of (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes [4]. In fact, back in 1972, this need to define "especially designed or prepared" (EDP) equipment and material led to the creation of the first suppliers' export control group known as the "Nuclear Exporters Committee," or "the Zangger Committee," and the first nuclear 'Trigger List' of items that would trigger the application of safeguards agreements.

The two separate systems maintain distinct objectives but serve common goals. The IAEA's safeguards conclusions serve as confidence building measures between States that their neighbours or rivals are not

[2] The Nuclear Suppliers Group includes 48 Participating Governments and the European Commission as Observer

[3] The 1540 Committee is an ad hoc committee mandated by UNSCR 1540 with the role to collect from States, review and approve information on the implementation of the Resolution. This information is organised in the so-called 1540 matrices and it is made available online.

developing nuclear weapons programs, providing some transparency and decreasing potential motivation for new States to develop nuclear weapons programs. Likewise, export controls promote lawful international trade while preventing the unauthorised access and use of materials, technologies, and equipment of nuclear proliferation concern. Both systems support the implementation of the NPT by promoting compliance with the letter and the spirit of international law. However, it is up to individual States to implement laws and regulations to enforce, detect, and prevent WMD proliferation.

Export controls and safeguards have been largely shaped by the same external factors and triggering events. For example, the 'peaceful' nuclear explosion conducted by India in 1974 demonstrated the need for adoption of full-scope safeguards along with enhanced export controls on the basis of common guidelines and led to the foundation of the London Suppliers Group, later renamed as the Nuclear Suppliers Group (NSG). In 1978, the NSG followed the work done by the Zangger Committee by extending the Trigger List to cover some items for heavy water production and adding further procedures and conditions such as formal governmental assurances, the application of safeguards, and strengthened re-export provisions [5].

In 1991, the discovery of undeclared proliferation activities in Iraq was a turning point for both safeguards and export controls, as it brought to the fore the role that dual-use technologies and equipment can play in the proliferation of WMD. In the export controls field, this realisation led to the establishment of an additional set of NSG guidelines for the transfers of dual-use items that could make potentially a significant contribution to an unsafeguarded NFC or nuclear explosive activity [6]. This also determined a paradigm shift in the implementation of safeguards that was demonstrated with the introduction, in 1997, of the "Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards" [7]. States signing an AP to their safeguards agreements agree to provide the IAEA with an expanded set of information and rights (e.g. additional information concerning NFC activities, broader access to locations into countries, and simplified procedures for travel and designation of inspectors) enhancing thereby the IAEA's ability to detect the presence of undeclared nuclear material and nuclear-related activities in a State [8].

In order to maintain the ability to make reliable safeguards conclusions, the IAEA, and Member State support programs, must develop new verification trends and technologies to stay apace with the evolving global environment in which they exist. The most recent trends in safeguards verification are the State Level Concept (SLC) and an exploration of emerging technologies.

The State Level Concept refers to "safeguards implementation that is based on State-level approaches developed using safeguards objectives common to all States with CSAs and taking State-specific factors into account" [9]. The safeguards objectives refer generally to the detection of diversion of declared nuclear material and the detection of undeclared material processing at declared facilities and locations outside facilities for States with CSAs [10], and, for States that have an Additional Protocol in force, to detect undeclared nuclear materials and activities in the State as a whole. Objectives that are more specific to the State are defined via the analysis of material acquisition pathways [11] and using six state-specific factors including the NFC capabilities of the State, the type of safeguards agreement in force and the technical capabilities of the State or regional system of accounting for and control of nuclear material (SSAC/RSAC) [9].

While the concept of evaluating the State as-a-whole originated in the IAEA's Programme 93+2 [11], the SLC further developed State-level assessments through the formalization of both acquisition pathway analysis and the State-level factors. Yet, even the State Level Concept continues to evolve, as can be observed through the implementation of the State Level Concept Improvement Project which is developing "methodologies and guidance to standardize and improve the internal processes for conducting acquisition path analysis, developing State-Level Safeguards Approaches (SLAs), and evaluating the effectiveness of safeguards implementation" [12].

The other recent trend in safeguards verification has been the assessment of emerging technologies to support nuclear verification efforts. The IAEA has hosted two workshops on emerging technologies and their potential to

address safeguards challenges, one in 2017 [13] and one in 2020 [14], and has posed multiple safeguards technology innovation challenges, including in the areas of robotics [15] and tomography [16]. One of the most striking trends in the assessment of emerging technologies for safeguards is related to data analysis. The emphasis on data analysis has included interest across analytical techniques and methods (e.g., business intelligence, machine learning, and artificial intelligence) and data sources (e.g. open source text and images, international trade data, process monitoring data, and safeguards surveillance data).

In the export control realm, export control systems need to keep apace with continuous technological developments [17], evolving trade patterns as well as geostrategic factors that may have an impact on the priorities and implementation of controls. For instance, technological advancements necessitate the swift update of control lists while global supply chains make difficult the identification of trade routes and end-user(s). Given that the update of control lists is entangled with foreign availability issues, technical complexity to introduce effective control text and other political and commercial interests, the implementation of controls on non-listed dual-use items based on their final end-use and end-user is a flexible mechanism implemented for several years by countries having adopted comprehensive export control systems. This trend is expected to last as so-called "catch all mechanisms" provide a possibility to oversee and if necessary, prohibit the export of a new technology whose control has not yet been agreed for some reason [17]. Dual-use exporters, from their side, have a responsibility to implement due diligence procedures to understand the potential applications of their products and assess the lawfulness and of their trade partners and operations. These internal measures can take the form of Internal Compliance Programmes (ICPs) which are considered by several export control authorities as a prerequisite for granting certain trade facilitations (e.g. general and global licenses) and evaluating the trustworthiness of an exporter. Moreover, the dual-use concept per se is broad enough and can accommodate diverse objectives and priorities. For example, the EU's new dual-use Regulation includes provisions for the control of technologies that can be misused for internal repression purposes and other human rights violations [18].

In an era of close international collaborations between industry and research organisations and of intensive scientific production, dual-use research is a topic of interest for both the export control system and safeguards system. Export controls intend to prevent the misuse of dual-use items that can be used as inputs in a research or can be the output of a sensitive research. A research project may involve the transfer of materials, equipment and prototypes or, data and software encoded in tangible means but it may also entail intangible technology transfers in the form of an email or a technical presentation in a conference, with the latter case posing great challenges to the implementation of controls. At the same time, the implications of dual-use technology transfers have bearings on State capabilities and related IAEA assessments for safeguards. As both systems are concerned with tracking State's capabilities as well as tracking research collaborations between countries, they can benefited by the applications of data mining technologies such as the newly developed TIM DU platform [31] which could assist with identifying potentially sensitive dual-use research collaborations and analysing State capabilities.

2. Interfaces between safeguards and export controls

2.1 Monitoring tangible nuclear exports

Export controls and safeguards historically developed in parallel and are linked elements of the non-proliferation framework, as indicated in both the NPT provisions [4] and the NSG Trigger List guidelines [5]:

- The Non Proliferation Treaty conditions the export of equipment or material especially designed or prepared for the processing, use or production of special fissionable material to any non-nuclear-weapon State to international nuclear safeguards [4, Art. III.2];
- The Nuclear Suppliers Group's Trigger List guidelines state that safeguards are a condition of supply for nuclear goods [5, Art. 4].

Thanks to more comprehensive States' reports and inspections, the IAEA can obtain further insights into a State's NFC related activities and capabilities. Particularly, States having signed an AP to their safeguards agreements provide declarations with information on the location/description of all NFC activities taking place in the State and specify the scale of operation in each location engaged in the fifteen NFC activities mentioned in the Annex I of the AP.

The AP also requires the provision of declarations with information (identity, quantity, location of intended use in the receiving State and date of export) regarding exports of all items listed in its Annex II and those related to the nuclear activities listed in its Annex I [Art. 2.a.(ix)]. The AP Annex II list of items uses essentially the NSG Trigger List (INFCIRC 254/Part 1) as adopted under its second revision in 1995.

On their side, export control processes authorize or deny export applications presented by traders to national licensing authorities. The information provided in a license application is evaluated by the authority to assess the proliferation risk associated with the specific trade transaction, and accordingly decide whether to authorize or deny the export. The information provided by the exporter in a license application differs among countries applying export controls. Common data fields include a description of the items to be exported, their value and quantity, the end-user, and stated end-use. When the export is authorized, a license is issued which may include conditions such as time of validity or to a maximum value/quantity of items that can be exported to a given destination(s) or end-user(s), depending on the nature of the licence. In any case, not all authorized exports necessarily take place due to changing market or business conditions. The use of a licence is often reported systematically to the licencing authority and post-shipment controls on the reporting is possible, taking into account customs related data from processed declarations.

As authorising, or when necessary, prohibiting the export of sensitive items remains a national prerogative under the implementation of national export control systems, these obligations under the AP create opportunities for synergies between safeguards implementation and the operation of export controls. Export control authorities can directly provide data about authorised exports to their colleagues responsible for AP declarations to IAEA. Furthermore, States may opt to provide voluntary IAEA with additional information concerning sensitive exports conducted that will allow the IAEA's Department of Safeguards to assess the nuclear capabilities of a given State.

For countries applying export controls, including the NSG-related, license data is by default not public. Some countries publish license data in aggregated format by type of items and destinations concerned, including some denials' data. For example, the United Kingdom publishes detailed licensing statistics on a regular basis [19]. The Netherlands makes available selected fields of raw data records about licenses since a few years [20]. Flanders (Belgium) also publishes monthly reports on the authorised and denied licences with details on the value, country of destination, country of end-use, dual-use classification number and the level of authority that made the decision [21]. In perspective, at European Union level, the recent recast of the Regulation for dual-use export controls introduced new measures on transparency about the implementation of controls, foreseeing the publication of license data aggregated by item type and destination and by EU Member State [22]. In the United States, the responsible jurisdictional agencies publish aggregate license data such as number of licenses, number of denials, and top Export Control Classification Number (ECCNs) annually based on the license applications received [23].

When published, and depending on the level of detail provided, license data can be analysed for safeguards purposes (i) as a 'look ahead' to potential exports, (ii) to better understand trade relationships between countries, (iii) and as an indicator of the importing countries' interest to make use of certain NSG-related items.

The export of dual-use items, as any other export, generate trade data that appear in declarations required by customs authorities. Aggregated export data is public for most countries [24] and it can be analysed for safeguards purposes [25, 26], even if the trade nomenclature in use in trade data sets, the Harmonized System [27], differs and is much less specific than the NSG lists. For some items listed as Trigger List items, the connection with AP requirements under safeguards agreements is evident as trade data can allow cross matching with export data

provided in AP declarations. For the same trigger list items, open source trade data may exist and be analysed for countries with no AP in place. Other dual-use nuclear related material and equipment and technologies listed under the second set of NSG guidance INFCIRC/254, Part 2 can also have an association to Harmonized System (HS) positions sufficiently precise to provide insights to safeguards analyses.

In addition, as the IAEA seeks to develop and reinforce the application of "State Level Approaches" (SLA) for effective safeguards implementation and verification processes, it is interested in having a deep understanding of a country's technical and industrial capabilities and the direction in which these are evolving. In particular, through the application of AP Analysis, the Agency evaluates all the possible routes at a disposal of a State for achieving weapons-useable material. In this context, open source trade data is also of use [28].

Nuclear export controls and export declarations under AP requirements are not based on identical lists. The AP Annex II list has not been amended since 1995 while the NSG Trigger List has been amended already several times with the current version being Rev. 14 of 2019. This fact creates discrepancies to exporters and authorities which is addressed in various practical ways as discussed in other papers [3, 8, 29]. A remedy to this discrepancy would be to update the list of equipment and material specified in Annex II of the AP. The procedure for updating the Annexes is described in Article 16 of the AP.[4]

Safeguards implementation can be benefited by information concerning -possibly- unfulfilled inquiries to authorities or companies. The IAEA created the Procurement Outreach Program in 2006, which established a channel for States and companies to voluntarily offer information related to export denials and business inquiries from suspicious customers [8]. Transactions rejected as suspicious by compliant exporters and denied license applications may provide indications of attempted efforts by State and non-State actors to obtain certain sensitive items including technologies and services. Companies and States have an interest to record and analyse such type of information to improve their own internal risk assessment procedures and comply with the export control law.

2.2 Monitoring intangible technology transfers

Besides dual-use systems, components and materials, also technology for the development, production or use of dual-use goods and software is fungible and provides the recipient with an enduring improvement in capabilities. [30]. The importance of technology transfers was acknowledged early and as such, the NSG and other international export control regimes include within the scope of their lists technology and software that can be used for the development, production or use of WMD and other conventional military items as well as for other dual-use items. Linked to this, the provision of technical assistance that takes place either remotely from a country's territory or in a foreign country can be also subject to an "export authorisation", depending on the national control provisions. It should be noted that information falling 'in the public domain' or qualifying as 'basic scientific research', is excluded from the scope of export controls.

In the safeguards domain, AP declarations provided in association to AP Annex I's list of NFC activities, include descriptions of nuclear research and development activities that may allude to nuclear technologies (and software to model/ assist nuclear processes) present in a country. However, under AP's Annex II declarations, IAEA Member States are not required to provide information concerning intangible exports of technology and software [32]. Export controls related data can provide insights to such blind spots in order to assess the technical and industrial capabilities of a given State. Again, this depends on the level of detail of license data with respect to technology transfers, and further, on the extent to which controls over technology transfers are effective. As technology can cross borders without leaving traces and through intangible means (e.g. an email), the practical implementation of export controls is very challenging and relies on the adoption of ICPs by exporters and ex post measures by authorities such as audits and, compliance inspections.

[4] The AP Annexes may be amended by the Board upon the advice of an open-ended working group of experts established by the Board. Any such amendment shall take effect four months after its adoption by the Board.

As data mining and management techniques improve drastically, researchers and authorities in the area of export controls are better equipped to map and assess collaborative research networks and entities conducting potentially sensitive research. For example, the European Commission JRC, in collaboration with Liege University, has developed the Tools for Innovation Monitoring Dual-use (TIM DU) platform [31] that facilitates the identification of entities publishing research with a dual-use potential in the various countries.[5] Together with many dual-use goods and emerging technologies, TIM DU maps NFC activities' results included in scientific abstracts, patents, and EU-funded projects, allowing analysts to gather lists of documents, geographical distributions, collaborations, and authors related to these activities. Save the need to analyse the papers to verify their actual dual-use potential, these results can help the national authorities submitting declarations to IAEA in accordance with Additional Protocol's Article 2.a, both to identify previously unknown national research actors and their collaboration networks, as well as to raise the awareness of national research entities about potential sensitivities with external collaborators. The IAEA could also use TIM DU to support the verification of the completeness and correctness of the declarations concerning nuclear fuel cycle research [32].

3. Identifying common challenges in data collection and analysis for safeguards and export controls

As chapter 2 demonstrated, the complementarity of safeguards and export controls' main objectives create opportunities for synergies such as using available data sources for multiple purposes and cross-matching data coming from varied sources. This is particularly true for safeguards, as the IAEA makes wide use of various information sources to detect potential indicators of undeclared nuclear material and activities in a State as a whole, and for States with an AP in place, to be able to derive broader safeguards conclusions on the absence of such activities. Similarly, export control authorities can also check export data against AP declarations and rely on various information sources used by safeguards experts such as public company websites and technology manuals in order to establish the plausibility of stated end-user(s) and end use(s) in a license application and any possible risks.

A first challenge concerns data openness and confidentiality issues. It can be argued that States and private companies are not always eager to share information on denied exports or procurement attempts of dual-use items for national security and foreign policy or commercial and industrial secrecy reasons. In cases where a State or private actor decide to share information through available channels (e.g. NSG meetings, IAEA Outreach Programme) a high degree of confidentiality is required and as such, relevant information may not be made public.

This challenge is also relevant to less sensitive license data such as information on authorised exports. As explained in 2.1, there are some States or international entities in the case of the EU which publish such data at an aggregate level. For example, while the US Department of Commerce publishes the number of licenses, exceptions, and top 10 ECCNs exported under certain types of authorizations, this does not provide enough detail to get an exact list of ECCNs exported to all countries [23]. Similarly, the UK releases export control licensing statistics, but the aggregate data does not provide enough specific information to accurately depict the flow of Annex II exports to other countries [33]. Moreover, this lack of data transparency extends to license exceptions used for safeguards-related exports [34]. Some States have implemented exceptions for international safeguards, but the lack of publicly available data on how and where the exceptions are used limit the current capability to use the data to support analyses and assessments. Another interesting point is that available data do not provide information on intangible technology transfers, their value, and end-user.

[5] The TIM DU's database relies on three types of datasets for its analyses: (1) scientific publications contained in SCOPUS, which is the largest abstract and citation database of peer-reviewed literature, covering over 45 million publications in all languages provided that at least the title and the abstract are written in English; (2) world-patents from the European Patent Office PATSTAT, covering more than 22 million patents issued by more than 90 patent authorities, including all the major countries, published in English; and (3) all EU-funded research projects throughout various research Framework Programmes, retrieved from the CORDIS website.

A further common challenge concerns the correlation between HS codes used in international trade databases and dual-use codes used in the export control lists by national export control authorities. In practice, this means that correlating international datasets with dual-use codes can be a difficult exercise as there is not always a one to one correspondence between HS and dual-use codes. For example, for some safeguard-relevant HS codes, there is also the issue that an HS code is too broad. Therefore, within one HS code, reporting on the import/exports may include items of safeguards interest, but it may not. In this case, further analysis is needed to pull out usable data for safeguards, such as determining the cost differences between a proliferation-relevant item and one not subject to safeguards.

As explained in section 2.2, TIM Dual-Use is a web-based platform retrieving publicly available data from various databases. Lessons learned while developping its capabilities to map dual-use collaborative networks and scientific production point to a number of challenges relating to access, collection, processing, and assessment of data.

To begin with, although TIM DU relies on public access sources, full access to related databases is sometimes subject to payment, which can amount to a sum that not all interested organisations are able or willing to pay every year. For example, while a subscription to Scopus abstract and citation database, used also by TIM DU to map potentially sensitive publications, one can access the abstracts, names of authors and their affiliations but access to full publications might require additional subscriptions.

Data collection can be also impacted by difficulties in the data processing phase. One of the main barriers could be the language as only few analytic tools can support multiple languages [35]. The second obstacle to overcome, especially for text analysis techniques, is the required level of technical knowledge and the human bias in the choice of the terms [36]. This point stresses the fact that text-mining results depend on the question that is asked. In TIM DU, search queries are visible to the user and performed exclusively in English, however, they can retrieve publications in all languages, provided that at least the title and the abstract are written in English.

Data structure and granularity are also key issues for data collection. Structured databases such as Scopus, contain well-organised data that are easier to extract and process compared for instance to news websites, which are less structured, and with a higher heterogeneity in terms of format [35]. Also, entity resolution is a relevant issue here. When data are retrieved from different sources, it happens that the same organisation is reported under different names or that there are some errors in the data, and thus, data harmonization and cleaning of the results might be necessary [35,36]. TIM DU's affiliation processing is performed by the "Entity Matcher" whose task is to identify the name variants of an organisation and attribute them a unique name and location.

Finally, an essential but challenging task, especially in text analytics, is the assessment of results. The results of text mining algorithms are based on keywords combinations. The more specific the combination, the higher the precision (relevance/usefulness) of the results, but this can impact data completeness (quantity), and vice-versa. Nevertheless, sometimes, even though the keywords are clearly relevant, the results might not be, mainly due to lexical ambiguity (e.g. searching for the combination of "seals" AND "nuclear", referring to the item controlled under Category 0 of the EU Dual-Use Control list, retrieved one document discussing the analysis of the "nuclear" DNA of the marine mammals "seals") [35]. To adopt an effective assessment strategy, search queries have to reflect a certain balance between precision and completeness in order to maximise the quantity of results while looking for the best possible relevance.

It can be argued that most of these identified challenges also concern safeguards experts who use text mining tools for their analyses. A further challenge more specific to data collection/processing for safeguards purposes is that a lot of useful information can be provided in the form of a video or image. Being able to collect and process multi-modal data is challenging because the subject matter is so specific and because a lot of the data could be unlabelled or improperly labelled making retrieval by a text search difficult. Further, there is just so much data out there that prioritization in a timely manner is difficult without identifying and using performant processing tools.

4. Conclusion: A way ahead

In conclusion, export controls and safeguards are inextricably linked, each maintaining clear, separate objectives that serve a common goal. The legal and theoretical framework enumerating how export control and safeguards complement one another have been well documented by the work of Sevini, et al. [3, 8, 29] and Peterson, et al. [2]. As such, a path forward for future research could further explore these findings by building out hypothetical case studies that incorporate the application of the TIM DU tool, data sharing, and other techniques for data extraction and analysis, while also considering and addressing challenges such as entity resolution, data protection, text analytics, and lack of publicly available trade data. These case studies could be used to identify recommendations for processes, tools, and approaches related to data collection, analysis, and data sharing and analysis between State authorities and the IAEA. Drawing from research from other disciplines that address some of the common challenges associated with applying new technologies could offer lessons or solutions to overcoming some of the challenges identified in this paper. The approaches that other fields use to address entity resolution, data processing and analysis, and data sharing likely offer valuable insights. Looking ahead, there are significant challenges to overcome for export control and safeguards verification processes, activities, and data to best support one another. This paper aims to provide a state-of-the-art account of the current nexus between dual-use trade controls and safeguards and the related challenges. Future research could focus on addressing those challenges to promote opportunities for synergies between strategic trade controls and safeguards in support of their shared goal towards nuclear non-proliferation.

References:

1. United Nations Security Council Resolution 1540 (2004)
2. D. Peterson, et al, "Export Controls and International Safeguards," The Nonproliferation Review, 2008, p. 515
3. F. Sevini, G. Renda, S. Cagno, X. Arnes Novau, C. Charatsis, W. Janssens, "Export control and nuclear safeguards", ESARDA Bulletin N.60. pp. 60-66, 2020
4. Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/140, 1970)
5. Guidelines for Nuclear Material, Equipment and Technology, (IAEA INFCIRC/254/Rev.14/Part 1)
6. Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Materials, Software, and Related Technology, (IAEA INFCIRC/254/Rev.11/Part 2)
7. Model Protocol Additional to the Agreement(S) Between State(S) and the International Atomic Energy Agency for the Application of Safeguards, (IAEA INFCIRC/540 -Corrected,1997)
8. F. Sevini, et al., "States' Reporting of Annex II Exports (AP) and the Significance for Safeguards Evaluation," IAEA Safeguards Symposium, 2014
9. IAEA, The Conceptualization and Development of Safeguards Implementation at the State Level: Report by the Director Genera, (GOV/2013/38, 12 August 2013)
10. The Structure and Content of Agreements between the Agency and States Required in Connection with the NPT, (INFCIRC/153 -Corrected, 1972)
11. IAEA, "Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System: Report by the Director General to the General Conference," (GC(39)/17, 22 August 1995)
12. IAEA Safeguards, "Development and Implementation Support Programme for Nuclear Verification 2020-2021," STR-393, January 2020, p. 74
13. IAEA Safeguards, "Emerging Technologies Workshop: Trends and Implications for Safeguards," (Workshop Report, February 2017)
14. IAEA Safeguards, "Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges," (Workshop Report. STR-397, 2020)
15. Mutluer, Adem, "Robotics Challenge Winning Design Helps Speed up Spent Fuel Verification," IAEA News Centre, 2019, March 18
16. Mutluer, Adem, "Winning Entries to IAEA Tomography Reconstruction and Analysis Challenge to Aid Safeguards Activities," (IAEA News Centre, 2019 November 29)

17. F. Sevini et al., “Emerging Dual-Use Technologies and Global Supply Chain Compliance,” IAEA Symposium on International Safeguards, Nov. 5-8, 2018 (conference paper)
18. REGULATION (EU) 2021/821 of the European Parliament and of the Council of 20 May 2021
19. https://www.gov.uk/government/statistics/strategic-export-controls-licensing-statistics-2020
20. https://www.rijksoverheid.nl/onderwerpen/exportcontrole-strategische-goederen/documenten/rapporten/2016/10/01/overzicht-dual-use-vergunningen
21. https://fdfa.be/nl/maand-en-jaarverslagen
22. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2021:206:FULL&from=EN
23. United States, Department of Commerce, Bureau of Industry and Security, “Statistical Analysis of U.S. Trade with the World.” 2020.
24. C. Versino, M. Tsukanova and G. Cojazzi, “Catalogue of Web Data Services on Global Trade,” ISBN 978-92-79-18919-7, 2010
25. C. Versino, et al., “Global Trade Data to Support IAEA Safeguards,” ESARDA Bulletin (45), 2010
26. E. Marinova, et al., “Analysis of Nuclear Relevant Information on International Procurement and Industrial Activities for Safeguards Purposes,” Symposium on International Safeguards: Linking Strategy, Implementation and People. IAEA, vol. IAEA-CN-220, Vienna, 2014
27. Harmonised System, https://www.wcotradetools.org/en/harmonized-system
28. E. Marinova, et al., “The Use of Trade Statistics to Map States’ Nuclear-Related Industrial Capabilities. Symposium on International Safeguards: Building Future Safeguards Capabilities,” IAEA, vol. IAEA-CN-267, Vienna, 2018
29. F. Sevini, “Nuclear Export Controls Update,” paper presented at the 55th INMM Annual Meeting, Atlanta, 2014
30. C. Charatsis, “Interferences between Non-Proliferation and Science: ‘Exporting’ Dual-Use Know-How and Technology in Conformity with Security Imperatives, PhD thesis, 2017, p. 49
31. Tools for Innovation Monitoring Dual-use (TIM DU) platform
32. F. Sevini, E. Caponetti, C. Charatsis, X. Arnes-Novau, “Supporting the Additional Protocol declarations on nuclear research and technology by the TIM DU platform,” ESARDA Bulletin N.62. pp. 43-59, 2021
33. United Kingdom, Department of International Trade, Export Control Joint Unit, “Strategic export controls: licensing data annual reports.” 2021 July 9
34. United States, Department of Commerce, Export Administration Regulations, 15 C.F.R. § 740.11.
35. O. Kononova, et al., "Opportunities and challenges of text mining in materials research," iScience, Vol. 24(3), March 2021
36. Talib, R., Hanif, M. K., Ayesha, S., & Fatima, F., "Text mining: techniques, applications and issues," International Journal of Advanced Computer Science and Applications, Vol. 7(11), 2016, pp. 414-418