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Innovation in Safeguards R&D and EU Contributions to Strengthening the Global Safeguards System

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Abstract. To address the safeguards challenges in a changing and transnational world, there is a need to combine the "classical" safeguards technologies, with new approaches and tools, which in some cases try to "think outside the box". Research and Development performed by the European Commission Joint Research Centre in this area, include advanced monitoring techniques, open source information and satellite imagery analysis, use of trade data and risk based assessment of sensitive technologies. A number of developments are done in close collaboration with its colleagues in other Directorate General of the European Commission (ENER, RELEX, DEVCO, TRADE etc), with the European Safeguards Research and Development Association (ESARDA), with IAEA, US-DOE, with facility operators and other international collaborations. This paper will illustrate a few of the latest developments with the example of "monitoring uranium enrichment facilities and related activities". A second part of the paper, describes the legal framework and instruments, at the disposal of the European Union, which support the developments to address the challenges and which seek to implement programmes to address global threats.

1. Introduction

The effective implementation of safeguards (including drawing up the country-specific safeguards evaluation report) continues to face a number of challenges, one of which relates to the detection of possible undeclared nuclear activities in a country. With the entry into force of the Additional Protocol AP (AP) [1] to the Comprehensive Safeguards Agreement (CSA) [2], the IAEA was provided additional means to address this challenge. Aspects like geo-political considerations, industrial capabilities, availability of trained scientists, amount and level of scientific publications and patents, or their absence despite a known capability, can contribute to the definition of a country's proliferation potential.

The verification of the addition protocol declarations requires multi-disciplinary techniques like e.g. use of satellite imagery, environmental monitoring and the emerging use of trade data analysis [3]. The potential of this technique is increasing [4] and this paper explains a number of potential application fields, while at the same time addressing a few challenges for the implementation and interpretation of the data of AP declarations.

To assess the identified challenges, a number of different phases are distinguished in this paper and proposals are being made how to address these challenges. They mainly focus on the analysis capability of additional indicators in the area of import/export of specific technology or the genuine development thereof. Where relevant, the concepts are illustrated with the example of a Gas Centrifuge Enrichment Plant (GCEP) for uranium enrichment.

The paper concludes with a short reference to EU nuclear security related programmes which can contribute to the development and implementation of the proposals suggested in the paper.

2. Detecting undeclared nuclear activities

Undeclared nuclear activities can misuse declared facilities, or rely on clandestine ones. The former case can be primary tackled by the implementation of "classical" nuclear safeguards, whereas the latter needs to rely on more sophisticated multi-disciplinary non-classical indicators.

2.1. Misuse of an existing/declared facilities

With the entry into force of the AP, the international safeguards traditionally based on NMAC, C/S and DIV have evolved towards the Integrated safeguards foreseeing unannounced, short-notice random

inspections, as well as complementary accesses. The next big challenge will be the progressive introduction of data transfer and remote monitoring.
A new opportunity is also represented by multi-lateral nuclear assurances relying on nuclear fuel banks open to countries officially renouncing to develop an enrichment programme, and also by trans-national nuclear fuel cycle facilities, with the additional possibility to handle the sensitive technology as a "black box" (i.e. only known to the current technology holders), as e.g. for GCEP.
Three well known "diversion scenarios" exist and will be developed in the next sections.

2.2. Undeclared facilities

The development and construction of an undeclared facility requires various phases and produces various types of emanations and indicators (Figure 1).

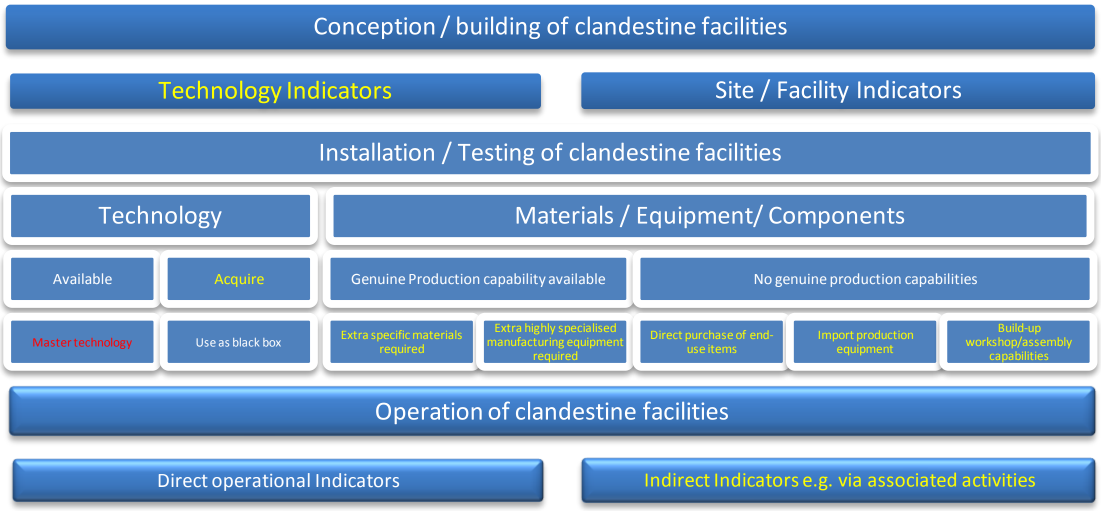

Figure 1: Scheme about the phases of detection for a clandestine facility (in yellow text where export control and trade analysis have potential applications and in red where process monitoring can apply).

2.2.1. The conception and building phase of a clandestine facility

During the initial ground-laying of a nuclear fuel cycle facility for U enrichment, either above or under-ground, there are no direct enrichment specific features which can be observed from satellite imagery. When evaluating which kind of technology (e.g. gas centrifuges, laser, magnetic separation etc…) could be deployed in a clandestine facility, one can look for "indirect" indicators e.g. on which technology a specific country has gained experience (e.g. through operation of declared facilities, R&D or strategic partnerships) or where active R&D is ongoing. Such indicators can be very useful in the early phase of discovery and are discussed below. It is noted that some nuclear fuel cycle facilities (like reactors) can have very visible signatures during the building phase, but this is not further elaborated here.

2.2.2. Procurement and installation of the relevant equipment in a clandestine facility

Installation of equipment means access to technology, materials, components etc, and know-how about how to use them. Contrary to the previous phase, when referring to the GCEP case, in this phase there are many potential specific indicators and a number of them might be "discovered" long time before the equipment installation phase.

2.2.2.1.Access to a specific technology and know-how about how to use it

In a specific country there will be typically two alternative situations: either the country is not known to operate a specific technology, or the country has already declared facilities where a specific technology is being deployed. In the first case, special attention needs to be dedicated to the *technology acquisition path*. In the second case, it needs to be analysed whether the technology is "only used", e.g. as a black box, for a very specific purpose or whether the country demonstrates to *master the technology* such that it can be deployed in clandestine way with or without substantial changes to the technology.

2.2.2.2. Access to materials, components and equipment.

To install equipment in a facility, not only the technology must be known but also the materials and components must be available. Again two cases are identified.

A first case where the country is known to have genuine production capabilities for the relevant equipment (because it has e.g. constructed already equipment for declared facilities). The discovery of "extra-production" for clandestine activities will then be a major challenge. In case *very specific materials* are required in the production of equipment or the operation of a clandenstine facility, for which e.g. only a few producers exist world-wide, an analysis can be made about the business relations, the procurement queries issued by the country under investigation and possibly relevant quantities of such materials exported to and/or imported by that country. In case *highly specialised manufacturing equipment* is needed for the production, one can analyse the existing production capability with the known machines and in case it is judged not to be available or sufficient for producing clandestine items, one can also analyse whether extra specialised machinery is being purchased.

The second case is where country has no declared production capabilities for relevant equipment. In such case two different acquisition pathways and scenarios can be analysed.

A first scenario pathway is based on direct purchase of finished materials and equipment. In cases where such items can be uniquely and exclusively associated to nuclear fuel cycle or weaponisation activities, the analysis would be facilitated because a discovery of (and attempt of) trade could be a sufficient indicator to ask for clarifications/special inspections in the country (this is similar to the "strong" indicators in the physical model [5]).

Art. 2a of the AP Annex I contains a list of 15 nuclear activities on which States are required to report "*a description of the scale of operations for each location engaged …*".

AP's Annex II contains a list of items derived from the Trigger List functional to Annex I's activities for which (Art. 2.a.ix) "*export… identity, quantity, location of intended use in the receiving State and date"* should be reported to IAEA.

Trigger list items, included in annex II of the AP, are hence the typical reference to analyse this direct purchase, but this is *not sufficient nor complete* because it does not include dual use equipment. According to the Physical Model they may provide weaker indicators, but this is not a reason why *analysis of trade of dual use items* should not be part of the verification activities of an inspection regime.

Ideally such analysis should include also *information/purchase enquiries, denials, licensed import/export and violations of trade*. In this respect, always according again to Art. 2.a.ix the AP gives the IAEA possibility to ask States to verify imports in selected cases, in order to cross-check declarations. But this is however only possible for Annex I activities, and Annex II items. A broader scope would hence be very useful.

The second scenario and pathway is represented by a country *importing production equipment* for the manufacturing of sensitive items and *builds-up specific production/workshop capabilities* to manufacture production equipment for the fabrication of direct use items. Trade analysis could in this case target dual use equipment *in special materials and machines for the production of equipment*,.

Recommendation to improve the analytical potential by expanding AP Annexes will be developed in the next chapter.

Finally under this header there is a clear link with the *annex I of the AP*, listing 15 activities, the execution of which is to be declared by the countries under the AP. A number of these activities have a direct link to the Annex II items of the AP whereas other activities can be linked to "dual-use" equipment [6]. For still others, there might be technology links which are neither trigger list nor dual use items. This paper will go in some detail on the need to provide additional support to the inspectors to verify the reporting on the annex I activities and/or the detection of clandestine activities such as those listed in Annex I.

2.2.3 Operation of the equipment / exploitation of a clandestine facility

Also in this phase of discovery of clandestine activities a few different cases need to be analysed. In the case where the "operation of a facility" can be associated with *activity specific indicators* (like power supply, effluents, specific releases, heat, noise or waste production etc…), one can specifically seek to discover one or more of such indicators through satellite imagery, remote monitoring, calculations, modelling and consistency analysis on the site. The latter is meant to stimulate inspectors, especially on

existing sites, to verify that the site lay-out, operator declarations, externally observable factors (like the ones indicated above), are consistent with the declared activities on a specific site. Extra buildings, changes in building or site lay-out, potentially underground facilities etc… might be overlooked on existing/declared sites, unless the inspectors are specifically trained to seek for "abnormal" or "inconsistent" features and have dedicated tools available (e.g. laser based DIV – and its potential application to GCEP facilities). Such features can of course also become strong indicators for clandestine facilities when discovered on non-declared sites (but this is a particular challenge if no supporting "intelligence" is available about where to look…).
Then there is the other case where the operation of equipment or exploitation of the facility does not a priori has strong observable indicators. It is clear that such operation will be much more difficult to discover, which is the reason why weak or indirect indicators need to be looked for, e.g. maintenance products, transport means, subsequent process steps etc. This means that when one is seeking to discover a specific clandestine activity via weak indicators only, a "scenario" is required about which other activities can be connected to the operation under investigation for the latter to make sense in a clandestine nuclear fuel cycle or weaponisation activity. This "indirect" discovery through scenario analysis and use of the methodologies is analogous to that described under paragraphs 2.2.1. and 2.2.2.

3. Verifying declarations on AP Annexes

AP annexes (I and II) were defined shortly after the detection of major clandestine activities (in this case in Iraq) and were relying largely upon previous work done e.g. by the Zangger Comittee and subsequently by NSG [7]. They were partially inspired on the shortly earlier introduced "Voluntary Reporting Scheme" to IAEA. The Annex II list of specified equipments indeed largely corresponds to the trigger list items, defined by the referred sources, as of 1995.

Based on this situation and the challenges described in paragraph 2 of this paper, four proposals are developed here to try and address the current safeguards challenges :

- Update annexes I and II and develop specific guidance for the verification of annex I activities
- Include import of specific items in annex II in both the declarations and especially the verification
- Integrate in the AP verification methodology both dual-use items and other specific items.
- Prepare a database on Violations of Export of Controlled Goods (VECG-DB)

The subsequent paragraphs will detail each of these proposals and propose some tools for the implementation. Upfront, it is recognised that there are associated concerns w.r.t. to the proposed implementation like the issue of "industrial esponiage" and the isssue of "controllability".

With respect to the first issue it is noted that this concern was expressed also at the time of the NPT conception in the late 60's [8] and was overcome. An explicit answer lies also in the AP articles itself w.r.t. confidentiality of the data [7]. One might also directly ask the (the consent of the) industrial companies, which often have a commercial interest to fully respect of export control regulations, i.e. for some companies it has become a quality label, company goal and one day possibly a strategic advantage to provide full data on dual use equipment production and export [9]. Finally the full political support from the UNSCR 1540 [10], NPT Review Conference Conclusions and the initiatives from NSG to initiate a major update/revision of their control lists, confirm the importance of import/export control, both nationally and multilaterally, with trusted partners.

A second concern is the "controllability" of the items, i.e. although a number of technologies, components, materials etc might be deemed very relevant, it is not straightforward for the inspectorates to find out whether a country has produced and/or purchased such items in a certain reporting period or not. The latter will depend strongly upon the tools available to which this paper tries to deliver a first contribution.

3.1. Updating the Annexes of the AP and support to improved verification

The AP annexes were develop in the mid-90's and not revised since then, it is hence highly recommended to update these annexes. This may require not only including items from the dual use list, taking into account NSG's Fundamental review of control lists, but also possibly expanding the Physical model. One example of missing technology and associated items is pyroprocessing.
Deemed even more important is the development of guidance for the inspectorates to verify the declarations

upon correctness and completeness, especially because clandestine activities would not be easily detected through more extensive declarations but in fact through an improved verification/assessment methodology.
In fact, when requesting the inspectorates to verify the absence of the activities under Annex I of the AP, one might profit from additional "checklists" or cross-correlations and/or structured background documents which illustrate the listed activities.

It is recommended to extend the availability of commodity guides, materials handbook, including, as deemed relevant also information on major producers, exporters, typical prices etc.[11].

3.2. Systematic evaluation of import data

For those items currently listed in the additional protocol, the prime focus lies on export and not on the declaration of import, which is to a certain extent surprising because a state evaluation report is focusing on a specific country so in first instance one would expect that the "import" of items is most relevant to judge the countries activities. Albeit the possibility to ask for import declarations for Annex II is foreseen under the AP, a more systematic declaration of import of such items is expected to be beneficial. This could be done voluntarily (i.e. not requiring an AP modification) (for both Annex II items and for Annex I related equipments) or obligatory, but it is deemed more important to verify import (even if not declared) in specific cases and for specific components, to check the completeness of the declarations on specific fuel cycle activities.

3.3. Integration of dual-use and other specific items in AP verification methodology

There are many dual-use items and watch-list items for which no AP coverage exists. It is not realistic to expect that world-wide import declarations for all individual dual-use items will reported to IAEA.
To address this challenge there are tools under development which allow to either specifically search for a particular type of import (e.g. from a known exporter to a suspected importer, e.g. during a given time frame) or which allow to monitor in general trade patterns e.g. of specific importers, to spot anomalies in either type of commodities, price level, quantities etc, which can trigger further investigations in a specific country or from specific exporters on a targeted item. These new approaches are known a "trade analysis for non-proliferation investigations" and a few examples have been published [12-14]. A more systematic use of this approach is advocated by this paper, stressing at the same time that further developments are needed, both w.r.t. to the interpretation of cross-correlations between the HS nomenclature and controlled commodities and w.r.t. the availability of data in the market place (noting that some regions/countries are providing no such information).
It is clear that these additional verification tasks need to rely on validated and traceable data sources. A number of sources exist already today, both free accessible and those requiring subscription fees (e.g. customs declarations, trade data bases) [15] and new developments in open source data mining are expected to enhance further considerably the potential of those assessments.
It is worthwhile to note at this stage that the inclusion of dual-use items under the AP verification's approach is only a first step. This is because when assessing "sensitive technology" one can identify three categories : firstly, the items under current export control regulations, secondly those military items not (yet) on the control lists and thirdly those relevant technologies which are not controlled (or controllable) or having been taken off the lists (e.g. because being to far spread to allow world-wide control). It is recommended that these two types of technologies, equipments, materials, components which are typically not addressed by the export control regimes, also merit close control / analysis and, in need be, inspections in very specific/targeted cases.

The first part not covered in current export control regulations is the still military/classified/secret part (labelled "sensitive" hereafter) which can normally be expected to be well-controlled and thus not easily accessible. In case of weaknesses in this protection on sensitive items however (like the historic alleged transfers of nuclear weapon designs to specific countries), the challenges lies in the discovery of such failed protection especially for those who do not have genuine insight in the sensitive technologies. This is a particular challenges for national implementation of export control regulations, e.g. in the European Union where such "sensitive items", even if not specifically listed, could fall under the catch-all concerns and thus would need to be addressed by industry, licensing and enforcement responsible, also in those member states not necessarily having the expertise in these fields. Although the debate on how to address this national challenge falls outside the scope of this paper, there is a direct link to the AP implementation (especially when it could be adapted to correspond better to the export control regulations) because the same difficulties of assessing sensitive items might be encountered at the international verification level.

A way to address this is to make sure that sufficient "sensitive" expertise is available to the inspection bodies, taking into account that such experts must be allowed access to inspect relevant locations, activities etc…Such "sensitive technology experts" can also produce targeted searches (e.g. in trade databases).

The second part, not covered in current export control regulations, are those technologies known to be in the common-marketplace (and thus e.g. deemed to be not (any longer) world-wide controllable or be subject to reporting obligations) but which can have a particular relevance to specific nuclear fuel cycle or weaponisation activities. It is not recommended in this paper to systematically include such items in current export control regulations, as this would not be feasible, but it is recommended, in specific cases, to compile lists of such "items" for specific end-users / destinations etc and monitor the trade-flow and/or use of such items to either detect some clandestine activities or to increase the confidence level on the absence of such undeclared activities. This idea is not new, in that a number of countries use so-called "watch lists" for certain destinations [16], associated to their export control regulations, but without the same legal character. The recommendation in this paper is that such watch lists should be used or, when not available, be specifically conceived, to support the verification activities under the AP.

3.4. Prepare a database on Violations of Export of Controlled Goods (VECG-DB)

In analogy to the Illicit Trafficking Database held by IAEA – Nuclear Security Dept and its potential link to nuclear safeguards and non-proliferation (for what concerns the nuclear materials) [17], it is proposed here to compile a database focusing on "Violations of Export of Controlled Goods (VECG-DB)". In order to compile such database (e.g. relying upon open source information and data mining techniques), one can use a scenario analysis to increase the chances of recognizing patterns and/or systematic anomalies. This proposal clearly goes beyond the export denials (for which IAEA already calls clearly upon states) and turned down purchase requests (where companies agree to spontaneously inform the IAEA of such events). It will indeed require a close collaboration between customs (enforcement) and licensing bodies, a collaboration from which both parties can be expected to profit. The parallel with the ITDB (esp. when including data w.r.t. nuclear forensics) holds also when investigating the specific procurement paths (and thus allowing to discovery of unknown origin, middle-man, trading patterns etc…)

4. Misuse of available technology

When a specific country already possesses the basic technology for civil/declared applications in a specific fuel cycle step, the IAEA needs to verify that such technology is not misused for non-civil applications, neither by duplication in non-declared facilities, nor by material diversion in declared facilities. Especially the first part constitutes a particular challenge when the footprint/indicators of the activities are rather small and e.g. installations can easily be constructed underground. In this case, an indirect assessment can include other indicators which would confirm or deny that associated developments are being pursued by a specific country which would point to non-civil applications of the declared technology. To stick to the example of GCEP, a first indirect indicator of the increased risk for potential misuse would be the either the production of higher grades of enrichment or the experimentation with the adaptation of the technology (in this case e.g. reconfigurations of cascades / centrifuges) to allow the effective production of higher enrichment grades. This is what was meant, at the onset of the paper, by improved mastering of the technology, which could be a hint towards potential non-disclosed activities. In other words, when an end-user operates a certain technology (e.g. GCEP based U enrichment) as a black box (and/or under multilateral supervision) to e.g. produce only 4 to 5 % enriched U, and cannot experiment with centrifuge parameters/cascade performance, this limits the experience gained to use in a hypothetical clandestine enrichment plant to produce HEU. To further verify absence of the latter, other indirect indicators would be sought for like the processes for producing U metal (especially when no other nuclear fuel cycle activities would require such processes) or the additional purchases of specific process equipment like pressure transducers [14], especially when the such equipment would be bought in a clandestine manner although it is operation officially also in a declared facility.

Another relevant concern is the verification of absence of diversion of materials in declared facilities, which in the case of a large scale U enrichment plant, e.g. based on GCEP, continues also to pose challenges esp. w.r.t. the efficiency of the verifications/controls/inspections. Therefore continuing research and development are required to improve the tools, approaches and methodologies to safeguards such facilities. This includes advanced NDA methods, UF6 container identification techniques, Design Information

Verification methods and recently also techniques will allow to “monitor” such facilities. The monitoring is particularly relevant in case of a “black box” operation scheme, which has been “advocated for” above as being a preferred way of operation to limit the proliferation risk of the use of sensitive technologies and can e.g. be implemented in GCEP plants. In such case, the focus of the monitoring will be on the consistency of the plant design and operation, input/output parameters, flow rates without disclosing classified parameters of the technology. The relevant signals are normal process control parameters. In cases where authenticated operator parameters are accessible to continuously monitor the plant, the spotting of anomalies, either triggering questions to the operator or even further inspections, will be facilitated. It is noted that, when combining a multitude of plant process parameters with sound statistical analysis and good process modeling a large number of process data variations, which could potentially trigger false alarms, can be eliminated through cross-correlations and consistency checks. Thus the disturbance to or interference with the operator will be brought down to minimum. This is an example of R&D, still required for routine facilities, to e.g. verify in more efficient manner that no material is diverted at the same, declared enrichment level or that no undeclared feed is being used. To link this issue with the previous paragraphs, an operation in a GCEP enrichment plant like cascade reconfigurations would highly likely be spotted in such continuous monitoring approach and could then be discussed with the operator to clear the anomaly.

5. Legal framework and EU support programmes in the area of nuclear security and non-proliferation

On the international scene a number of quite recent legal and political initiatives were taken which either directly or indirectly support the use of trade analysis for non-proliferation purposes. This is the case with the UNSCR-1540, the Nuclear Summit in Washington, April 2010 and the NPT Review Conference 2010. In their 2008 report, the World Custom Organisation emphasized the importance of enhanced export control for non-proliferation [18]. In the European Union, as follow-up to the 2003 Security Strategy and associated developments, a very explicit call is made for enhancing export control in the “New Lines for action for Combating WMD”, approved in December 2008 [19].

With respect to the financial instruments available to allow funding of related activities, two EU programmes, with an international dimension, are highlighted here. The first programme which covers the more “classical nuclear safeguards” approaches is the *Instrument for Nuclear Safety Cooperation* [20]. The second one is the *Instrument for Stability* [21] under which the nuclear activities related parts come in under 4 chapters:

- Nuclear security culture
- Decommissioning of weapons facilities and redirection of former weapon scientists
- Combating illicit trafficking of nuclear materials
- Export control on sensitive technologies (industry outreach, licensing, enforcement)

Projects can be funded, both bilaterally and regionally, in almost any area of the world. A prime focus is put on South-East Asia, Middle-East, Caucasus and North-Africa and other regions will follow.
For this paper especially the 4th bullet (export control) merits special attention to contribute directly to enhanced safeguards and non-proliferation assessments. In the approach to the indicated regions, it is important to convince them of the relevance of a well established export control regime, not only to fulfill their international obligations (UNSCR 1540) but also to allow them to assess risks and make investigations in the non-proliferation area, both for their own country and on an international level (e.g. assessing relevant trans-shipments and/or to verify that there is no under-cut of national restrictions on trade of specific commodities)

Inside the European Union relevant initiatives which can support the ideas put forward in this paper can be found in DG TRADE, responsible for the unique EU export control legislation [22] (COM 428/2009), in DG HOME, responsible for the EU CBRN policy and corresponding action plan [23] and in DG TAXUD, responsible for customs. Specific studies are being carried out to identify gaps and corresponding solutions to improve the efficiency and effectiveness of the systems in place in the EU.
Finally the industry can play a major role in developing and sharing best practices w.r.t export control, especially in those branches where the production of sensitive items is a major part of the business and/or in those countries where potential sanctions for violations are high. The collaboration with industry, including convincing them that a trade-analysis based approach will not lead to industrial espionage, will be

beneficial to continue to move in the indicated direction.

6. Conclusions

To address some of the challenges identified in the detection of clandestine activities, this paper recommends the enhanced use of export control related information (control lists, watch lists etc) and trade data in support to the verification of the AP declarations. The recommendations are thus mainly oriented towards the "verification methodology". It is also clear that with an increased level of declarations by states, an enhanced analysis e.g. by IAEA is possible. A few quite recent EU initiatives are providing funding to develop additional tools/approaches to support this area of work.

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