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A Technology Assessment Methodology for Arms Control

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Intro

One of the challenges when considering verification strategies for arms control treaties, is choosing from an array of potentially suitable technologies. This paper develops a methodology for systematically evaluating technologies in an arms control scenario, to identify tools and techniques to use in a verification regime. This paper then applies the developed methodology to several technologies, NQR (Nuclear Quadrupole Resonance), PGNAA (Prompt Gamma Neutron Activation Analysis) and HPGe (High Purity Germanium), to test their application in identified use cases within a verified dismantlement scenario.

The methodology formed in this work has proven able to show where technologies may encounter challenges in a defined verification regime. The methodology across the three technologies explored was found to be generally applicable. As developing technologies have been considered during this work, such as that of NQR, the assessed technology is not assumed to be a piece of COTS (Commercial Off The Shelf) equipment. Instead, the assessment corresponds to the capabilities of a well-engineered application utilising the technology.

Methodology

A rich picture has been used to provide a systematic approach, to evaluate technologies. Evaluating criteria are defined and a technology is assessed within developed use cases against these criteria. Developed for explosives, this methodology is applied to nuclear material in the application and results sections to show its resilience.

The rich picture and wider system of interest

The ‘rich picture’ captures all relevant aspects of the wider system of interest surrounding, and affecting, a problem. The rich picture, shown in Figure 1, was used to identify use cases for explosives measurements in connection with dismantlement of nuclear warheads.

In a treaty governing nuclear weapon reductions, a wide range of verification activities might occur. This work focuses on the processes around dismantlement. Dismantlement is the process of separating explosives from special nuclear material (SNM) and other essential components. The process may include interim steps, e.g. movement of explosives between points and temporary storage of explosives within the segregated dismantlement area. The central ‘dismantlement process’ is assumed to occur in a defined area to which the monitoring party has no access during the dismantlement operations but may have some access before and after. Access by inspectors during dismantlement operations is restricted to adjoining areas, where ‘input streams’ and ‘output streams’ may be monitored.

Input comprises of warheads and empty containers for accountable items resulting from dismantlement. The TAI input comes from the stockpile, under a broad provenance i.e. warheads coming from in-service, from long term storage etc. Empty containers (before use) and other process inputs (tools, chemicals etc.) may be more easily inspected at a point further ‘upstream’ than the more restrictive ‘pre-dismantlement’ environment adjacent to the dismantlement process area.

As shown in Figure 1, output consists of several, individually containerized streams that are still accountable (and inspectable). One stream consists of explosives removed from the dismantled object which could be monitored to test solely presence. Other process streams consist of non-explosive components and could be monitored for absence of explosives. There is also a process ‘waste’ stream, with materials and items that are not accountable but could be monitored for absence of explosives. Output components and process waste may also be inspected in a more accessible setting, referred to in Figure 1 as ‘pre-disposition’, than the immediate ‘post-dismantlement’ area, provided that suitable chain of custody measures are applied between post-dismantlement and pre-disposition. Finally, the rich picture shows a possible sample analysis laboratory, on-site but removed from sensitive areas, where samples of explosive may be taken for analysis, by the inspectors.

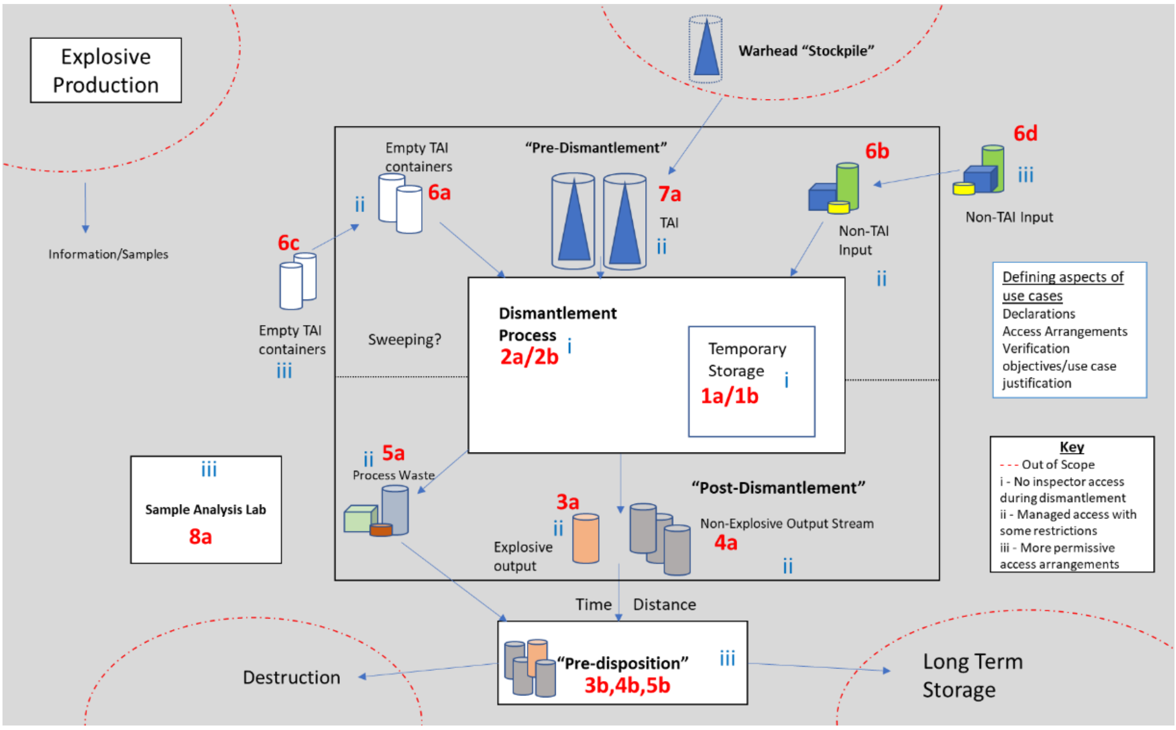

Figure 1: Dismantlement facility rich picture

The process steps and areas in the rich picture are subject to different constraints and restrictions regarding access by inspectors. Access restrictions influence the requirements of use cases, as the feasibility of verification measurements may be reliant on different levels of access. We have modelled access constraints on a scale of:

i) No inspector access during dismantlement. (When warhead components are not present this area may become level ii.)
ii) Managed access with major safety and security concerns.
iii) Managed access with more permissive safety and security concerns.

Assumptions and definitions

Some assumptions were made to refine the scope of the system. A key assumption was that warhead dismantlement takes place in only one area of a facility. Another is that measurements are per item, affecting measurement time and the footprint of the equipment evaluated. Use cases involving a warhead have a higher level of security; this limits the inspectors level of access for some of the use cases (see for example use case 7 in Table 1). Some use cases rely on other aspects of an arms control system, e.g. Chain of Custody remaining intact throughout, for the use case to be applicable. As the use case evaluation criteria only looks at the immediate logistical implementation impacts, these other systematic logistics are assumed to work as intended and be out of the scoring scope.

Use cases

From the rich picture in Figure 1, eight main groups of use cases for explosive measurements were identified. The use cases are examples of where monitoring may occur and not that all use cases apply simultaneously. Each use case is considered independently of the verification system it might be in and it is not mandated that all use cases will apply in a system.

These 8 main groups of use cases were sub-divided by specifying the measurement application and access constraints for that application in each setting. Access constraints would be informed by the scenario i.e. a State’s specific security and safety requirements for inspector access. The resulting set of 16 use cases is in Table 1, and their numbered location within Figure 1.

	Verification objective	**Measurement application**	**Measurement point/area (access constraint class i - iii)**	**Use case**
1	Unattended monitoring during the dismantlement process	Verify movement of essential components (**unattended**)	Dismantlement process area (i)	1a
		Verify inventory at various process steps (**unattended**)	Dismantlement process area (i)	1b
2	Material balance monitoring with respect to explosive	Sweep process area before and after (absence of explosive)	Dismantlement process area and adjacent areas (i, ii)	2a
		Verify declared explosive inventory before and after	Dismantlement process area and adjacent areas (i, ii)	2b
3	presence of explosive in correct output stream from dismantlement of a warhead	Explosive **present** in declared explosive output	Immediate post-dismantlement (ii)	3a
			Pre-disposition staging (iii)	3b
4	absence of explosive in non-explosive output streams from dismantlement	Explosive **absent** in non- explosive output	Immediate post-dismantlement (ii)	4a
			Pre-disposition staging (iii)	4b
5	absence of bulk explosive in dismantlement process waste	Explosive **absent** in process waste	Immediate post-dismantlement (ii)	5a
			Pre-disposition staging (iii)	5b
6	absence of explosive in non-warhead input streams to dismantlement	Explosive **absent** in process input	Immediate pre-dismantlement (ii)	6a,b*
			Upstream storage/supply chain (iii)	6c,d*
7	presence of explosive in object to be dismantled (declared warhead)	**Presence** of explosive in object presented for dismantlement	Immediate pre-dismantlement (ii)	7a
8	confirmation of declared explosive characteristics by analysis of explosive samples	Sampling and analysis	On-site dedicated/segregated laboratory (iii)	8a
	* 6a and 6b refer, respectively, to absence confirmation for empty containers that have design details that may be sensitive (furnishings for sensitive components or similar), and to other input that does not generate such concerns. 6c and 6d differ in the same way.			

Table 1 Use cases considered for explosive measurements in connection with warhead dismantlement verification.

Specific system information, and the amount of information that is revealed by a technology, may have to be protected. Technologies may reveal specific type(s) of explosives, physical constraints, shapes, or isotopic composition etc. Table 1 use cases were sub-divided according to what information must be protected, resulting in a total of 39 use cases with different requirements on information protection. These will not be described in detail except for the use cases discussed in the results.

For use cases where “exact mass and *possible* explosive types” should be protected, verification must resort to a templating procedure. The details of how such a measurement could be designed, the confidence gained, and the feasibility of such a process, differs for different technologies. Initial warhead providence for the warhead used in the first template, was not considered within this project.

Different technologies require emphasis on different protection of sensitive information risks, and the sub-division of 39 use cases is specific to NQR, the first technology explored. Other technologies might have a different set, for imaging technology, sensitivities around component shapes might determine the final sub-division. If a full use case list applicable to any explosive measurement technology is required, the list will contain numerous “degenerate” use cases when applied to a specific technology.

Assessing the application of a technology in a use case

To assess the use of a technology in a given use case, five ‘categories’ of evaluation were defined. The categories are broken down into a total of twelve ‘criteria’, each represented by a ‘value statement’ that can be fulfilled to varying degrees.

Category / Criterion	**Value statement** (…about the technology …in the use case)	**Comment**
Characteristics of technology		
Intrinsic limitations	Intrinsic limitations will not prevent effective use	Can the equipment perform the required measurement
Measurement sensitivity	Measurement sensitivity is sufficient	
Ease of falsifying result	Results are robust to attempts of falsification	This will have a different meaning for a presence/absence use case
Protection of sensitive surplus information	Possible surplus information is easily protected from release	How easy it might be to implement an information barrier
Complexity of equipment		
Transparency of operation	Results are obtained through a process that allows effective monitoring	Understanding of the function, complexity of equipment
Logistical demands		
Footprint	Footprint will not prevent effective deployment	Size, internal measurement distance (scattering, count rate), exclusion zone, shielding, etc.
Auxiliary services/utilities	Need for auxiliary services will not prevent effective deployment	Three phase power, batteries, liquid nitrogen, etc.
Access constraints	Access constraints will not prevent effective deployment	Primarily related to safety and security concerns from interaction with the measured object
Impact on surrounding operations	Deployment will not have unacceptable effects on surrounding operations	The extent to which operation of equipment impacts other activities, directly or through e.g. implementation of safety and security protocols
Process demands		
Measurement time	Measurement time will not prevent effective use	
Environmental control	Required degree of environmental control will not prevent effective use	Temperature, humidity, etc.
Ability to make relevant conclusions		
Supporting information required	Acquiring necessary supporting information does not introduce unacceptable additional issues	

Table 2: Categories and underlying criteria with value statements for evaluating a technology in the context of a given use case.

The 'intrinsic limitations' of a technology determines if the fundamental properties of a technology make it applicable in a use case and was judged to be different from 'measurement sensitivity' issues. The latter are defined by details of geometry, amounts, background and similar factors.

The aim of the 'Protection of sensitive surplus information' criterion is to protect surplus information from being revealed. Thereby scoring how easy it would be to implement an information barrier for the technology in a particular use case. This is not straightforward, as information barriers can come in many forms and at many points during data acquisition. For example, an NQR-specific information barrier may not be applicable to a gamma neutron activation analysis system, such as PGNAA, since respective measurements reveal different characteristics of a substance. This does not pose a problem to the methodology as it does not aim to compare between technologies. It does, however, mean care must be taken when discussing what kind of information barrier is needed for a particular technology in each use case.

For a technology, the value statement representing a given criterion from Table 2. We used a scale as shown in Table 3.

Label / Colour code	**Judgement on basis of criterion X**	**Employment of technology in the use case…**
A	Value statement is true	…would be straightforward
B	…	…would introduce minor difficulties
C	…	…would introduce major difficulties
D	Value statement is false	…is unlikely to be feasible
		…with respect to criterion X

Table 3: Scoring system used for each criterion (with value statement) listed in Table 2.

Application

The methodology was tested by applying it to two explosives verification technologies, NQR and PGNAA as well as an SNM verification technology, a HPGe detector. A description of technology and analysis outcome are outlined below.

NQR

NQR measures resonances (transition frequencies) of quadrupolar nuclei within an electric field gradient, measuring a response from N-14 nucleus. Explosives usually contain a high proportion of nitrogen. NQR for the N-14 nuclei differ based on their position within the explosive molecule, giving a unique response. One key benefit of NQR is its capability to identify presence to a high degree of confidence, and identifies chemical bindings, not simply ratios between elements. A downside is the potentially long detection time. This is not a major limitation as the throughput and measurement times would be under an agreement between treaty partners. Temperature regulation is critical, as it influences the frequency at which NQR lines are identified. Samples containing metal can produce "ringing" effects, this can make detection of the signal harder, although it can be mitigated with sophisticated signal input pulses.

The NQR use cases were sorted according to the occurrence of difficulties in the criteria for each use case. Use cases with minor difficulties are shown in Table 4, with the associated scoring results shown in Table 5. Use cases with the fewest difficulties for NQR are those verifying presence in the correct output stream, and verifying explosives declared in areas connected to the dismantlement area. These can be considered the 'use cases' which NQR is most suited for nuclear arms control verification objectives. There were no scores indicating NQR would be unsuitable for explosive detection within the context of verified nuclear warhead dismantlement.

2b1	Verifying the declared explosive inventory in facility areas connected to dismantlement (before and after). The exact explosive type is declared, with lower limits on mass and the container properties.
2b2	Verifying the declared explosive inventory in facility areas connected to dismantlement (before and after). A list of explosives are declared, with lower limits on mass and the container properties.
3a1	Verifying the presence of explosive in the correct output stream. Declarations for this use case include the exact explosive present, container properties and a lower limit of mass. The siting for this use case is in the post-dismantlement area, near to the dismantlement area.
3a2	Verifying the presence of explosive in the correct output stream. Declarations for this use case include a list of explosives (which contains the one present in the output stream), container properties and a lower limit of mass. The siting for this use case is in the post-dismantlement area, near to the dismantlement area.
3b1	Verifying the presence of explosive in the correct output stream. Declarations for this use case include the exact explosive present, container properties and a lower limit of mass. The siting for this use case is pre-disposition staging, further away from the dismantlement area.
3b2	Verifying the presence of explosive in the correct output stream. Declarations for this use case include a list of explosives (which contains the one present in the output stream), container properties and a lower limit of mass. The siting for this use case is pre-disposition staging, further away from the dismantlement area.

Table 4. The use cases with only minor difficulties when assessing the NQR technology, see Table 5 for scoring.

	Characteristics of technology				**Complexity of Equipment**	**Logistical Demands**				**Process Demands**		**Ability to make relevant conclusions**
Use case #	Intrinsic limitations	Measurement sensitivity	Ease of falsifying result	Protection of sensitive surplus information	Transparency of operation	Footprint	Auxiliary services/utilities	Access constraints	Impact of technology on surrounding operations	Measurement time	Environmental control	Supporting information required
2b1	A	B	A	B	A	A	B	B	B	A	B	A
2b2	A	A	B	A	B	A	B	B	B	B	B	B
3a1	A	A	B	A	A	A	B	B	B	A	B	B
3a2	A	B	A	A	B	A	B	B	B	B	B	A
3b1	A	B	A	B	A	A	A	B	A	A	B	B
3b2	A	B	A	A	B	A	A	B	A	A	B	B

Table 5: Scoring results for selected NQR use cases.

18 use cases presented at least one challenge which may make the use case unfeasible. Use cases that include measurements on metal, are especially difficult for NQR in the 'intrinsic limitations' criterion. Other difficulties for NQR are in the 'ease of falsifying results' criterion. Scoring as "unlikely to be feasible" in use cases for verifying absence, due to the ease with which explosives can be obscured from the NQR detector e.g. wrapping explosives in metal foil.

Some criteria of the NQR technology pose few challenges in any use case e.g. the 'impact on surrounding operations' criterion. This is because NQR does not emit ionizing radiation, although use cases where processes or materials sensitive to radio-frequencies may be impacted. Another aspect was the 'protection of sensitive surplus information' criterion. NQR is capable of showing only if an explosive compound is present, and is not be capable of showing what the sensitive property is.

PGNAA

PGNAA uses both different underlying physical processes and detected signatures to NQR. PGNAA identifies all elements in a sample via gamma spectroscopy; it identifies elemental composition, unlike NQR which identifies unique compounds.

Tables 6 and 7 show the use cases where the employment of PGNAA would only introduce minor difficulties. Use cases with the fewest difficulties were verifying absence in the non-TAI inputs to the dismantlement area; verifying presence in the correct output stream; and verifying explosives declared to be in areas connected to the dismantlement area.

2b1	Verifying the declared explosive inventory in facility areas connected to dismantlement (before and after). The exact explosive type is declared, with lower limits on mass and the container properties.
2b4	Verifying declared explosive inventory in facility areas connected to dismantlement (before and after), only container properties declared
3b1	Verifying the presence of explosive in the correct output stream. Declarations for this use case include the exact explosive present, container properties and a lower limit of mass. The siting for this use case is pre-disposition staging, further away from the dismantlement area.
3b3	Verifying the presence of explosive in the correct output stream. Declarations for this use case include the exact explosive present, container properties and a lower limit of mass. The siting for this use case is pre-disposition staging, further away from the dismantlement area.
5b1	Verifying the absence of a specific explosive type in process waste further away from the dismantlement area, in pre-disposition staging.
5b2	Verifying the absence of a list of explosive types in process waste further away from the dismantlement area, in pre-disposition staging.
6a1	Verifying the absence of a specific explosive type in empty input containers that will have TAI components just prior to the dismantlement area.
6a2	Verifying the absence of a list of explosive types in empty input containers that will have TAI components just prior to the dismantlement area.
6b1	Verifying the absence of a specific explosive type in input non-TAIs (except empty containers from 6a) just prior to the dismantlement area.
6b2	Verifying the absence of a list of explosive types in input non-TAIs (except empty containers from 6a) just prior to the dismantlement area.
6c1	Absence in empty input containers that will have TAI components - 'supply chain', not in access level ii, more permissive
6c2	Absence in empty input containers that will have TAI components - 'supply chain', not in access level ii, more permissive
6d1	Absence in input non-TAIs (except empty containers from 6a) - 'supply chain', not in access level ii, more permissive
6d2	Absence in input non-TAIs (except empty containers from 6a) - 'supply chain', not in access level ii, more permissive

Table 6. The use cases with only minor difficulties when assessing the PGNAA technology.

For PGNAA only two use cases are so challenging as to make the use case unfeasible; these look at presence of explosives in the input stream. The main challenge for PGNAA (like NQR) was the ‘protection of sensitive surplus information’ criterion, the information leakage risk is high because neutrons may activate materials in the field of view, not just explosives of interest. In contrast to PGNAA, major difficulties with NQR fall within the ‘intrinsic limitations’ criterion. As PGNAA utilises neutrons, it may be unsuitable due to criticality safety concerns in use cases where fissile material is present. This is reflected with the major difficulties found for the ‘access constraints’ criterion for some use cases.

The ‘environmental control’ criterion presented no difficulties in any use case for PGNAA, as the technology is self-contained; the detector relies on incident neutrons so excess neutrons are not a concern. The technology is also robust against temperature changes and RF signals. The ‘intrinsic limitations’ criterion also presents no challenges in any use case, as the technology is penetrating. In contrast to the NQR use cases the ‘supporting information required’ criterion for PGNAA templating would likely be less challenging since it would involve an information barrier. As a result, no such use cases were considered unfeasible for PGNAA. Instances when the ‘supporting information required’ criterion does pose major difficulties for PGNAA, do not occur in templating use cases.

	Characteristics of technology				**Complexity of Equipment**	**Logistical Demands**				**Process Demands**		**Ability to make relevant conclusions**
Use case #	Intrinsic limitations	Measurement sensitivity	Ease of falsifying result	Protection of sensitive surplus information	Transparency of operation	Footprint	Auxiliary services/utilities	Access constraints	Impact of technology on surrounding operations	Measurement time	Environmental control	Supporting information required
2b1	A	A	B	A	A	A	B	A	B	A	A	A
2b4	A	A	A	B	B	A	B	A	B	A	A	B
3b1	A	A	B	B	B	A	A	A	B	A	A	B
3b3	A	A	A	B	B	A	A	A	B	A	A	B
5b1	A	B	B	B	B	A	A	A	B	A	A	B
5b2	A	B	B	B	B	A	A	A	B	A	A	B
6a1	A	A	B	A	A	A	B	A	B	A	A	B
6a2	A	A	B	A	A	A	B	A	B	A	A	B
6b1	A	A	B	A	A	A	B	A	B	A	A	B
6b2	A	A	B	A	A	A	B	A	B	A	A	B
6c1	A	A	B	A	A	A	A	A	A	A	A	B
6c2	A	A	B	A	A	A	A	A	A	A	A	B
6d1	A	A	B	A	A	A	A	A	A	A	A	B
6d2	A	A	B	A	A	A	A	A	A	A	A	B

Table 7: Scoring results for selected PGNAA use cases.

The criteria with difficulties found in NQR and PGNAA are not the same, showing that this is a true evaluation of the technology. The complementary nature of the difficulties imply that future verification systems will have options for suitable verification technologies in the system

SNM utilising HPGe

Gamma-ray spectrum analysis utilising a High Purity Germanium (HPGe) liquid nitrogen cooled detector was chosen as it is a very common technology for SNM detection and characterisation. The technology is similar to PGNAA but differs by not activating the material, measuring instead gamma-rays that are emitted via possible spontaneous radioactive decay in a material.

The use cases were re-formulated for SNM, set in the same scenario they only needed minor modification. The main differences between explosive and SNM use cases were in the breakdown of the 16 use cases by information to be protected, as SNM emits radiation specific to isotopic composition. The SNM use cases were divided protecting the following properties: none; exact mass; exact isotopic composition; exact isotopic composition and exact element; exact mass, exact isotopic composition and exact element. This resulted in a 61 use cases for SNM, compared to 39 for explosives. A selection of these use cases was assessed.

Table 8 shows selected use cases and Table 9 shows the scoring results. Use cases presenting minor difficulties included presence declarations on SNM output containers, and absence declarations on non-SNM output streams, post-dismantlement.

3b1	Presence of SNM in correct output stream. No constraints
3b2	Presence of SNM in correct output stream. Exact mass protected
3b3	Presence of SNM in correct output stream. Exact isotopic composition protected.
3b4	Presence of SNM in correct output stream. Exact isotopic composition and exact element protected.
3b5	Presence of SNM in correct output stream. Exact element, isotopic composition and mass protected
3b6	Presence of SNM in correct output stream – mass, isotopic composition and element protected, templating use case.
4a1	Absence in non-SNM output streams, post-dismantlement. No constraints
4a2	Absence in non-SNM output streams, post-dismantlement. Protection of non-SNM sensitive information

Table 8. Representative presence and absence use cases for SNM detection.

	Characteristics of technology				**Complexity of Equipment**	**Logistical Demands**				**Process Demands**		**Ability to make relevant conclusions**
Use case #	Intrinsic limitations	Measurement sensitivity	Ease of falsifying result	Protection of sensitive surplus information	Transparency of operation	Footprint	Auxiliary services/utilities	Access constraints	Impact of technology on surrounding operations	Measurement time	Environmental control	Supporting information required
3b1	A	B	A	A	B	A	B	A	B	A	B	B
3b2	A	B	A	A	B	A	B	A	B	A	B	B
3b3	A	B	A	B	C	A	B	A	B	A	B	B
3b4	A	B	B	C	C	A	B	A	B	A	B	B
3b5	A	B	B	C	C	A	B	A	B	A	B	B
3b6	A	B	A	B	C	A	B	A	B	A	B	C
4a1	A	B	B	A	B	A	B	A	B	B	B	B
4a2	A	B	B	B	C	A	B	A	B	B	B	B

Table 9. Scoring of the representative use cases for SNM, evaluated for gamma-ray spectrum analysis utilising HPGe technology.

Modifying use cases from explosive to SNM detection was straightforward and the methodology can cope with different detection technologies and materials; shown by the scoring of SNM use cases which demonstrated no notable difficulties. Beyond changes to use cases depending on setting and objectives, care must be taken when considering final sub-division. This division depends on the employed technology and inherent properties of detected material. The intrinsic property of SNM to give off a radiation signature resulted in a larger set of information that potentially needed protection, which in turn yielded more use cases than for explosives.

System Discussion

Information obtained from a technology assessment, is useful for identifying which technology may be more suitable for use. The framework cannot compare between technologies; it cannot advise on the preferred choice where two different technologies have no major difficulties in a use case e.g., verifying declared inventories in a dismantlement area before and after the dismantlement process, and pose no major difficulties either NQR or PGNAA. The level of abstraction for both the rich picture and the scoring means that the information gained is necessarily vague.

All criteria are equally weighted. For example, if a technology presents difficulties in ‘measurement time’ we cannot say if this is harder or easier to solve than another which has a difficulty in the ‘protection of sensitive surplus information’ criterion. Even though a use case presents the same monitoring opportunity, different technologies fulfil the use case differently, whatever system “value” is in a specific scenario; specificity of explosive, or material amounts, etc. are not reflected in the scoring.

The framework considers technologies to be comparable, however for a specific scenario a solution may be found more easily for one technology. Such as, verifying presence of a minimum amount of declared explosive in the input warhead, overcoming the difficulties associated with protection of sensitive surplus information *may* be easier than overcoming intrinsic limitations. The reasoning behind this stems from the decisions to assign unfeasible difficulties in these cases. For NQR the presence of a large amount of metal surrounding the explosive will be challenging. For PGNAA the difficulty is the risk of information leakage, combined with the complexity of an information barrier. This risk is subjective and is assigned here as unfeasible but, given the right managed access and information barrier, a way might be found to overcome the difficulty.

These use cases were formed from assessing all points within the system of interest and where measurements could be made, not by assessing a verification system on a particular State or in a specific facility. The chosen focus system does not consider the entirety of where explosives may be found. Possible strengths or weaknesses of a technology not apparent in the formed use cases, will not be revealed in the analysis. The chosen focus system is appropriate for the present study, but care must be taken when sketching and analysing the wider system of interest, to ensure no features are neglected.

Conclusions

This paper has shown a methodology for systematically evaluating technologies in an arms control scenario which can identify promising techniques to use in a verification regime. The methodology was tested on several technologies and has proven able to show where technologies may encounter challenges in a defined verification regime. All three technologies were able to be assessed using the framework.

Being able to apply a specific technology in a specific environment will lead to much more concrete results but would be too specific to be considered as a future path for this programme of work.

References

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