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The United Kingdom – Norway Initiative: Further Research into the Verification of Nuclear Warhead Dismantlement

Working Paper submitted by the Kingdom of Norway and the United Kingdom of Great Britain and Northern Ireland

Summary

Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) sets out, among other elements, that each of the Parties to the Treaty undertakes to pursue effective measures relating to arms control and disarmament, non-nuclear-weapon states and nuclear-weapon states alike. Establishing effective verification measures will be an important precondition for fulfilling the goals of Article VI. Since 2007, the UK-Norway Initiative (UKNI) has explored activities in line with these obligations, with both Parties mindful of their roles and obligations under international agreements and national regulations.

This Working Paper details the outcomes since the 2010 Review Conference of the collaboration between experts from Norway and the United Kingdom to further investigate technical

and procedural challenges associated with a possible future nuclear disarmament verification regime. Since then:

The UKNI undertook a ‘focused’ exercise in 2010 which explored the impact of Host security and safety measures on the inspection regime. The exercise demonstrated how security and safety requirements are essential for the development of verification technologies and procedures.

Norway and the United Kingdom held a workshop in London in December 2011 to discuss in detail the work of the Initiative with interested parties from twelve non-nuclear-weapon states and the United States of America. The participants agreed that major development is still required to produce verification technologies and procedures in which all parties can build and maintain confidence.

A series of student exercises has been taking place since 2013. The exercises have been designed in partnership with King’s College London to facilitate academic research and investigate factors that contribute to the building of confidence in an inspection process. The exercises have also furthered the education and outreach aspects of the UKNI by providing relevant experience to the next generation of verification practitioners. Six exercises have been conducted to date, with participants from universities in Egypt, Germany, Russia, South Africa, the United Kingdom and the United States.

Work on the UKNI Information Barrier has continued throughout the 2010-2015 period. The focus of this project has been to understand how to build technologies in which both parties can maintain confidence. The Information Barrier has been developed to determine if the ratio between quantities of plutonium-239 and plutonium-240 in a plutonium sample is above an agreed threshold. The project has focussed on how to perform this analysis without revealing classified information, with consideration of how to interpret results returned by the instrument in an operational environment.

In the future, the Initiative will continue its work to provide deeper understanding of the application of the results so far by further considering the contexts in which verification may take place. The United Kingdom and Norway take this opportunity to encourage the wider international

community to make its own contributions to the ultimate objective of an effective nuclear weapon dismantlement verification regime.

I. Introduction

1. Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) sets out, among other elements, that each of the Parties to the Treaty, both non-nuclear-weapon states (NNWS) and nuclear-weapon states (NWS), undertakes to pursue effective measures relating to nuclear arms control and disarmament under strict and effective international control. The establishment of effective verification measures will be an important precondition for fulfilling the goals of Article VI.

2. The UK-Norway Initiative (UKNI) is an ongoing collaboration between a NWS and a NNWS which seeks to investigate technical and procedural challenges associated with a possible future nuclear disarmament verification regime. This has been a process of building trust and cooperation in an area which also presents political challenges. The principal objectives for the collaboration are:

- To create scenarios in which Norwegian and United Kingdom participants could explore issues relating to nuclear arms control verification without the risk of proliferation.
- To promote understanding between a NWS and a NNWS on the issues faced by the other party, particularly in relation to a nuclear weapons dismantlement verification regime.
- To promote discussion on how a NNWS could be involved in a nuclear arms control verification process.

3. The UKNI presented its initial work at the 2010 Review Conference.[1] This Working Paper includes the outputs since then and builds on work presented to the NPT Preparatory Committee meetings held in 2012, 2013 and 2014.

II. Background

4. The UK-Norway Initiative was established in 2007. It is the first time that a NWS and a NNWS have attempted to collaborate in this field of research. Representatives from four Norwegian laboratories, the Institute for Energy Technology (IFE), the Norwegian Defence Research Establishment (FFI), NORSAR and the Norwegian Radiation Protection Authority (NRPA), together with representatives from the Atomic Weapons Establishment (AWE plc) in the UK, have participated in the Initiative, with oversight from the Ministry of Foreign Affairs in Norway and the Ministry of Defence in the United Kingdom.

5. The efforts carried out under the UKNI since the 2010 Review Conference fall into three main areas of research: 'Managed Access', 'Information Barriers' and 'confidence in verification processes'. All areas of research are aimed at developing effective verification measures which protect proliferative or otherwise sensitive information whilst providing sufficient, accurate and truthful information for verification purposes.

III. The Managed Access project

6. In a future verification regime for nuclear warhead dismantlement, Inspecting Parties are likely to request access to highly sensitive facilities and weapon components. Entrance into sensitive facilities by any person not normally authorised to enter may only be granted once arrangements have been made

[1] Issued as Working Paper NPT/CONF.2010/WP.41.

by the facility to protect sensitive information. In the case of warhead dismantlement, access by Inspectors will have to be managed carefully by the Host Party, both to maintain compliance with the NPT and in consideration of national security. 'Managed Access' is the term used to describe the planning, methods and processes implemented by the Host to enable Inspectors to access specific locations.

7. The UKNI has continued to explore how inspections can be carried out, practically, at the facility level. The first UKNI Managed Access exercises were successfully run in Norway in 2008 and 2009 and were reported to the 2010 Review Conference. They were followed by an exercise carried out in the United Kingdom in December 2010. The Managed Access exercises were underpinned by a framework which included a hypothetical Treaty between two fictitious countries: the NWS 'Torland' and the NNWS 'Luvania'.

8. The 2010 exercise explored the impact of Host security measures on the inspection regime. It also incorporated elements of the safety regulatory environment associated with a nuclear weapons complex. In order to achieve the level of realism required, the exercise took place in a facility at the Atomic Weapons Establishment in the United Kingdom, with the United Kingdom taking the role of the NWS Host Party, and Norway playing the Inspecting Party. The facility used was in an area not associated with the dismantlement process of the United Kingdom, but many of the techniques and processes which might be deployed to manage access within a typical nuclear weapons complex were suitably mimicked, for instance checkpoints and controls which were set up to exercise the increasing levels of security that would have to be encountered when accessing a storage or receipt facility (Figure 1).

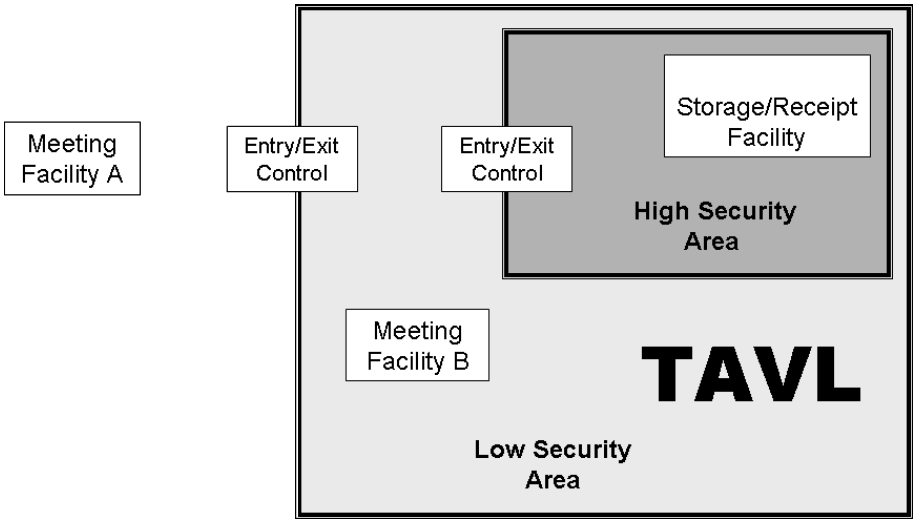

Figure 1: TAVL, Torland's 'Atomic Weapons Laboratory'. The sketch indicates the facilities and functions relevant to the 2010 exercise.

9. This arrangement had three advantages:

- It provided an opportunity for Norway to play the Inspecting Party, in a reversal of roles from the 2008 and 2009 exercises in Norway.
- The exercise benefited from the expertise of AWE's staff and utilisation of AWE's existing infrastructure.
- The arrangement satisfied both countries' concerns that obligations relating to NPT Articles I and II would be met during the planning and conduct of the exercise.

10. The exercise focused on a 'familiarisation visit' to a storage/receipt facility. The Inspecting Party was tasked to:

- Understand relevant processes, routes and facilities by obtaining access to the initial storage/receipt facility.
- Become familiar with the container types that would be used in the dismantlement process.

- Consider methods for sealing containers (the familiarisation visit included an opportunity to trial potential seal types on the exercise container).
- Consider a deployment method for a radiation detector with an Information Barrier.
- Consider an inspection strategy for a future monitoring regime, with regard to sealing the container and performing meaningful measurements with the radiation detector.
- Maintain the safety and security of the team and comply with all obligations under the NPT.

11. The Host Party was given the objective of protecting national security and proliferation sensitive information whilst demonstrating compliance with their obligations under the bilateral Treaty. The Host was instructed to:

- Place an emphasis on maintaining security as a first priority.
- Be reactive rather than proactive concerning requests from the inspectors.

Summary of events

12. The primary objective for the Inspectors was to understand relevant processes, routes and facilities by obtaining access to the initial storage/receipt facility. The primary objective of the Host was to protect national security and proliferation sensitive information whilst demonstrating compliance with their obligations under the Treaty. Host security and proliferation concerns meant that the Inspectors did not receive design plans of the facility. Furthermore, ambiguity in the language used by the Host to describe the facility, both during discussions and within the supporting documentation, resulted in misunderstandings between the Parties with regards to the function of the storage/receipt facility. In partial compensation for the lack of building schematics, Inspectors entered the facility with a view to clarifying the situation they faced. However, potential material diversion routes could not be identified due to the lack of information and because of the restrictions placed on the freedom of movement of the

Inspectors in the facilities. The Inspectors left with an incomplete overview of the facility and related operations, and were not certain about how the operations discussed linked to the overall dismantlement process.

13. Security concerns also prevented the Host Party from discussing the construction of the type of container used in the dismantlement process. As a result, Inspectors could not develop sufficient knowledge of the container to assess the effectiveness and vulnerability of either the seals or the radiation detector technology. A lack of information about the facility in which the radiation measurement system was to be deployed also prompted questions about the Host's ability to 'spoof' the measurement, and so a suitable inspection strategy was not developed.

14. The Inspectors found that the safety regime inhibited them more than they had expected. Explosives and fire regulations impacted upon Inspectors' preferred plans, the time available in the facility to execute those plans, and communication between Inspectors. The overall result was to exacerbate ambiguities regarding the processes to be verified and complicate the inspection process.

Lessons from the exercise

15. Both Parties must understand the objectives of any visit to any Treaty relevant location. The Host must assess the risks and consequences of disclosing information about those locations. A range of options can then be developed to enable access to facilities so verification objectives can be met without compromising facility security concerns.

16. During the development of Managed Access plans, the Host should consider if relevant 'national security' information may be disclosed as part of the Treaty. Disclosure may affect the operational priorities for information security arrangements under any such Treaty, so Managed Access plans should be developed in consideration of this altered security environment.

17. It is possible for a NWS to develop generic Managed Access plans ahead of agreeing to a monitoring process with a Treaty partner, but specific Managed Access procedures can only be finalised in agreement with the Treaty partner. Plans must be *mutually suitable*, fulfilling the Host's security objectives and also suitably facilitating the Inspectors' verification objectives.

18. Multiple facility visits are likely needed during procedure development in order to ensure that Inspectors develop sufficient knowledge about the various locations and processes. The exercise experience suggests that significant discussions about facilities and operations are likely required well before any facility visits or inspections take place. A desirable outcome of these discussions is a clear set of well-defined inspection procedures that reduce ambiguity, set expectations and define rights and responsibilities when performing specific verification tasks.

19. It is likely that existing facility procedures and processes will need to be modified to incorporate Managed Access requirements. Approval of modifications could take a significant amount of time since the consent of all domestic regulators will be required. Nevertheless, the overall result would be standard facility operations which can set realistic expectations on all sides. In contrast, ad hoc Managed Access arrangements could exacerbate ambiguity because extreme caution on behalf of the Host may require significant restrictions to be placed upon the visit.

20. It was evident from the exercise that Managed Access procedures must extend to equipment as well as inspection personnel. Equipment security must be considered at all stages of deployment, operation and retrieval, if both parties are to maintain a high level of confidence in the integrity of the equipment and if the equipment is to be used successfully for its intended purpose.

21. Clear definitions of facility specific terminology should be provided, and relevant facility information communicated unambiguously during the development of Treaty procedures. This is particularly important when the Host is unable to discuss certain details because of proliferation or

national security concerns. In practice, circumstances in an operational facility may require additional information to be exchanged between parties *in situ* as verification measures are implemented.

22. It is useful to deconstruct the terms ‘classified’ and ‘sensitive’ in regard to information and information security, and determine the reasons for classification. Some forms of ‘classified’ information may help facilitate the inspection processes if disclosed. To facilitate Treaty objectives, states may consider a reciprocal mechanism to exchange some sensitive information while ensuring that it is protected from wider public disclosure. An example might be information relating to elements of the physical protection infrastructure of facilities. With suitable preparations, the Host facility could implement alternative security arrangements to compensate for the disclosure of such information. Information of this type is clearly different from the type of ‘classified’ information widely regarded as proliferative or relating to warhead designs, but its classification will still complicate an inspection process if not considered beforehand.

23. The exercise highlighted the advantages of a proactive, cooperative Host in the facilitation of a successful inspection process. However, only a set of agreed, unambiguous procedures can mitigate the risk of changes in behaviour of either Party.

IV. The Information Barrier development project

24. ‘Information Barriers’ are an important concept when considering future inspections: Inspectors cannot be given unrestricted access to nuclear warheads since such access would breach the non-proliferation obligations of the NPT. Such access might also reveal national security sensitive information. Nonetheless, nuclear weapons may exhibit certain attributes that could help distinguish them from other items. A method to interrogate the attributes of sensitive items without breaching non-proliferation obligations may therefore be useful.

25. Conceptually, an Information Barrier (IB) is a system consisting of both technical and procedural elements, designed to prevent information regarded as sensitive by the Host Party from being disclosed to an Inspecting Party whilst allowing Inspectors to confirm agreed attributes. An IB takes measurement data, processes them relative to predetermined criteria and provides only an unclassified output.

26. In 2007, the United Kingdom and Norway embarked on the joint development of an IB system in which both parties to a Treaty would be able to build and maintain confidence concerning both operation and output. The effort is ongoing and currently the UKNI IB system is capable of confirming, in a laboratory environment, the presence of 'weapons grade' plutonium (in this case defined as plutonium containing greater than a predefined fraction of the isotope plutonium-239). For an IB to be effective, both parties must have confidence that the pass/fail output accurately reflects the state of the object being tested in an *operational* environment. The challenge now is to interpret results when the IB is used to analyse data collected from an unknown item (or series of items) in an operational environment.

27. Any fissile material (such as plutonium) produces a characteristic gamma radiation signature that can be used to confirm its presence and determine its isotopic composition. However, the Host Party may regard as sensitive the exact isotopic composition of the fissile material used in its nuclear warheads. Acknowledging this sensitivity, it might be considered suitable just to confirm that the ratio between certain isotopes in the material exceeds an agreed upon threshold, and so it is this approach that has been taken by the UKNI. The 'ratio' is a simplified measurement of the relative amounts of two of the major plutonium isotopes, plutonium-239 and plutonium-240.

28. The UKNI effort is unique because it involves a NNWS in the joint development of a measurement system; therefore no information that could be considered proliferative has been discussed or used at

any point, either explicitly or tacitly. Use of the IB will be planned and conducted so as to not alter this situation.

29. The UKNI IB is a custom designed, relatively low cost, light-weight, battery-powered, modular system that can be easily transported and used in the field (Figure 2).[2] The electronic unit is built from standard, commercially available electronic components. The design has allowed the project team to consider how to turn the concept of an 'Information Barrier' into an instrument in which both partners can build and maintain confidence in an operational environment.

30. The early stages of this development were presented in our Working Paper to the 2010 Review Conference. At that time, only subsets of the required analysis were considered, and surrogate materials were used in place of plutonium. Since 2010, the system has been developed to measure plutonium and carry out the full analysis necessary to confirm its presence and assess its isotopic composition.

31. In order to test how the IB works in a realistic environment, a series of measurements were conducted during the autumn of 2012 in a nuclear licensed facility in Dounreay, Scotland, in the presence of inspectors from Euratom. The samples of plutonium measured exhibited a range of isotopic ratios, and the mass of each sample was in the order of hundreds of grams. Following testing, the IB was modified to improve the accuracy of the calculated results. In 2014, the improved analysis technique was tested against a number of internationally recognised standard plutonium samples, which also exhibit a useful range of isotopic ratios. The results have been used to evaluate the performance of the IB and to evaluate the rates of false positives and negatives one might expect in a laboratory setting. More importantly, the results of these tests are being used to consider how to interpret results in an operational environment when the isotopic ratio of the object being measured is unknown.

[2] A more detailed description can be found in K. Allen et al., *UK-Norway Initiative (UKNI) approach for the development of a Gamma Ray Attribute Measurement System with an integrated Information Barrier*, ESARDA Symposium 35th annual meeting, Bruges, Belgium, 28-30 May 2013.

Figure 2: The UKNI Information Barrier. An external gamma radiation detector is connected to the system.

32. The IB has been designed with two different versions of software: One version uses a high level language (Ada) which is converted by a compiler into the binary code used by the instrument. The second version uses a low level language (assembly code) which uses a utility program called an assembler to create the binary code. The two different approaches were taken to investigate whether one approach would be easier to authenticate than the other, since this relates to how parties can build confidence in the correct functioning of the instrument. Both versions of software have been implemented to perform the same mathematical analysis of data collected by the measurement system.

33. The IB project will publish a series of detailed reports later in 2015, allowing interested parties to access details of the design, analyses, commentaries, conclusions and recommendations from the project. The UK and Norway hope that this resource will be used by others to take forward additional research and development of Information Barrier technology.

34. It must be stressed that the resulting UKNI IB is a research tool used to understand how to build and maintain joint confidence in verification equipment. There are a number of factors that would make

operational deployment and use of the Information Barrier challenging. Further discussion of the challenges will be published as part of the technical reporting of the IB project.

V. Confidence in verification processes

35. Confidence and confidence building is at the core of any verification process. It is likely that the wider international community will have more confidence in a verification process developed through multinational dialogue, rather than in a strictly bilateral process. In order to participate in that dialogue, States require appropriate knowledge and expertise. For this reason, Norway and the United Kingdom have made efforts to encourage other NNWS to carry out work in this field.

UKNI International Workshop in London December 2011

36. On 7-9 December 2011, the United Kingdom and Norway hosted a three day Workshop which aimed to bring together NNWS to discuss verification tools and methods needed to verify nuclear weapons dismantlement. It demonstrated how dialogue between NWS and NNWS on issues relevant to verification research can be facilitated, and explored how all States Parties to the NPT can contribute to their NPT Article VI obligations. The Workshop drew upon UKNI experiences up to that time and provided an important opportunity for attendees to provide feedback to the United Kingdom and Norway.

37. The Workshop programme covered policy and technical issues, and the delegates covered a broad range of relevant experiences, including direct experience of arms control regimes and nuclear safeguards. Invitations were sent to States that had previously expressed an interest in the UKNI, and twelve NNWS and one NWS (the United States) sent delegates, with the latter providing additional subject matter experience.

38. A number of topic areas were discussed during the three days of the Workshop:

- *Verification concepts and technologies*, including Information Barriers, chain of custody approaches and Managed Access.
- *The initialisation problem*: How one ensures that an item entering a verification regime really is the item it is claimed to be. This is particularly relevant for items that are proliferation sensitive, as their sensitive nature will limit the amount of information available to the Inspecting Party.
- *Declaration sufficiency:* How much information Inspectors may require in order for effective and meaningful verification activities to be conducted. How the Host could compensate for gaps in inspector knowledge due to information restrictions.
- *Confidence:* How to build sufficient confidence when access to information and facilities is limited by national security or non-proliferation obligations. Delegates suggested that this would more probably be achieved if the verification regime in question addressed wider elements of the nuclear weapon lifecycle (Figure 3). It was noted that the need for confidence impacts at all levels from negotiation to equipment design and operation.
- *Host/Inspector relationship:* Potentially conflicting information requirements of the Host and the Inspectors can lead to tensions during site visits, even though both Parties want the regime to succeed. Clearly agreed requirements and objectives should help to create a framework within which the inspection can proceed and a successful conclusion be reached.

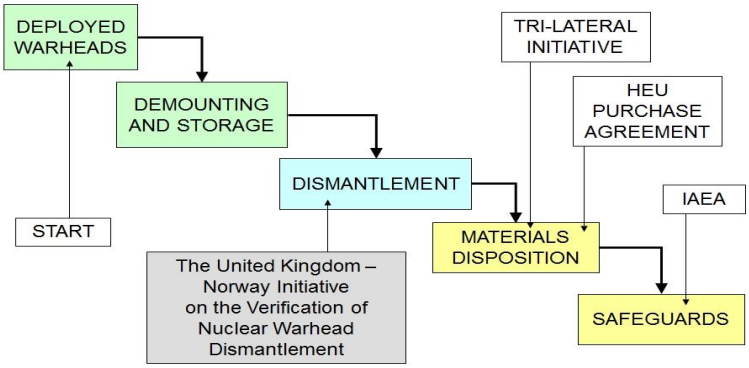

Figure 3: The UKNI (2007 – present) and other initiatives in relation to the stages of a nuclear weapon disassembly process. The Trilateral Initiative (1996-2002) was a US/Russian/IAEA programme of work to demonstrate practical approaches to IAEA verification of classified forms of weapons-origin fissile material. The HEU purchase agreement (1993-2013) between the United States of America and the Russian Federation provided Low Enriched Uranium (LEU) fuel for use in US nuclear power reactors, made by down-blending Highly Enriched Uranium (HEU) from the Russian nuclear weapons stockpile. The agreement allowed for monitoring of the down-blending process by the US.

39. Delegates were also asked to give feedback on the UKNI research programme, and any ideas that they felt would be useful for our work:

- *Value:* Forums like the UKNI Workshop are very helpful to explore verification issues in more detail, and exercises can be particularly good for exploring issues and promoting a discussion of them.
- *Exercises:* The programme of exercises was viewed as an effective way of identifying new issues, exploring scenarios and minimising the risk of failure in the future. But it was noted that

the results of future exercises may be different if the cultures, backgrounds and experiences of the participants were varied.

- *Incentives*: Both Inspectors and Host have an incentive for the regime to succeed since failure would reflect badly on the overall process and may adversely affect the international reputation of the Host.
- *Designated or dedicated facilities:* It was recognised that the existing facilities of potential Hosts were not designed with inspections in mind and that inspections could inhibit necessary ongoing routine operations. It was noted that a dedicated facility might help to facilitate the verification process; though many technical verification issues could still remain. It was also noted that the cost might be prohibitive.
- *Language and understanding:* Different interpretations of words or phrases might exist between Treaty partners, and establishing common definitions would be useful. This further supports the motivation for NWS work on a mutually acceptable glossary of nuclear weapon-related terms.
- *NNWS involvement*: Some delegates felt that NNWS involvement would be essential if a future warhead dismantlement verification regime was to be internationally credible and transparent. It was recognised that all States Parties to the NPT have an obligation under Article VI to contribute towards nuclear disarmament, and as such all State Parties are stakeholders in the development of verification regimes. It was recognized that active NNWS involvement in the inspection process brought both benefits and risks.
- *Technology Development*: There was widespread acceptance that major technological development is still required to produce jointly trustable systems for deployment in the verification of nuclear warhead dismantlement.

International student verification exercises in Norway

40. States may need to build knowledge concerning nuclear warhead verification challenges. Meanwhile, exercises can be particularly good for promoting a discussion of the challenges faced in verifying the dismantlement of nuclear weapons. To build on this the UKNI, in cooperation with King's College London, has developed a set of student exercises involving participants from international institutions. The exercises promote understanding and discussion, and they provide relevant experience to the next generation of verification practitioners. The exercises draw upon the lessons learned from the UKNI exercises that took place between 2008 and 2010 and draw upon feedback from the workshop. Six exercises have taken place since 2013, involving student participants from academic institutions in Egypt, Germany, Russia, South Africa, the United Kingdom and the United States.

41. The exercises have been designed in order to provide a rich, immersive environment in which participants can experience verification challenges first hand. The students are provided with a set of background materials to ensure that all participants are suitably aware of their rights and responsibilities within the exercise scenario. The level of detail minimises any exercise uncertainty experienced by the participants:

- Each exercise has been preceded by a number of lectures concerning the challenges faced in the field of nuclear warhead verification.
- An initial mission briefing is given which ensures that participants are suitably aware of how Treaty related activities should be carried out and how Treaty interactions between the Parties should work.
- Managed Access protocols are in place and are understood by all Parties (through the briefing).
- Similarly, Treaty aims and objectives, inspection processes and procedures and terms of engagement are all defined.

Academic study of trust and confidence in cooperation with King's College London

42. Confidence building is at the core of any verification process. Confidence in verification processes is particularly challenging during the verification of nuclear dismantlement because the Inspectors cannot be given unrestricted access to the dismantlement process itself. Following the series of UKNI exercises in 2008, 2009 and 2010, questions arose regarding 'confidence': What does it mean to have 'high confidence' when working in a restrictive environment where access to information and facilities is strictly controlled? How is confidence developed or lost? How can confidence be measured? How much confidence is 'sufficient' in the context of verifying nuclear warhead dismantlement?

43. The student exercises developed with King's College London have specifically been designed to facilitate a study on confidence building and a deeper understanding of the concepts of *confidence* and *trust*.[3]

44. Technical information relating to confidence and human factors relating to trust are controlled and observed for effects on the overall inspection assessment. Data are collected from the student participants using a variety of methods throughout the exercise. Questionnaires, interviews, focus groups, observations and real time, 'in play' feedback are all used to gather information. Analysis of the data is in progress, and the results of the study will be published by King's College London.

VI. Lessons learned

45. The three strands of research by the UKNI allow lessons to be drawn pertaining to several different aspects of nuclear weapon dismantlement verification from a variety of different activities. They can be grouped into five broad areas: the importance of understanding the wider context for verification; issues related to declarations, information exchange and Treaty protocols; the evolution of trust and

[3] For the purposes of the study, King's College London treats *confidence* as what you *know* to be true (an evidence-based judgement) and *trust* as what you *believe* is true (positive expectations about another's motives and intentions with respect to yourself).

confidence throughout a verification process; the conduct of inspections; and the development of verification technologies.

Understanding the context

46. One of the overall lessons is that progress can be challenging to achieve without a well-developed understanding of the context in which verification activities are to take place (be they technology development or inspections). For example, Inspectors in the UKNI Managed Access exercises found it difficult to assess their own inspection requirements for a particular facility because the scenario they were presented with did not include sufficient details of the wider nuclear enterprise of which that facility was a part.

47. It follows that the whole situation regarding the scope and provisions of a proposed Treaty is important. It is difficult to assess the value to an Inspector, or risk to the Host, of any individual inspection activity, measurement or event, without considering this contextual information.

48. A holistic view will allow a balanced assessment of requirements to be made in terms of the information required to verify adherence to a specific Treaty in relation to the aims and objectives of that Treaty. A holistic view may better identify the necessary level of access to locations and facilities, the tasks to be completed at those locations, and the technology needed to perform specific tasks. The value of particular inspection activities and exchanges of information can then be assessed in terms of overall verification objectives.

49. Verification solutions for nuclear Treaties must clearly be acceptable to all States party to any given Treaty. This means that these States will need to work together to identify their verification requirements and to develop processes and procedures to meet those requirements, bearing in mind proliferation and national security concerns. Context is again important since facility security concerns will vary depending on the information that has been declared and agreed for verification.

Information exchange and Treaty protocols

50. In order to allow a holistic view, the Parties involved in a verification process will need to exchange a large quantity of information. Some of this information exchange will be in the form of verifiable declarations, but much will also be supplementary information exchanged to allow the effective conduct of verification operations. Operational and facility-related information, for example, could be important in allowing Inspectors to contextualise the activities or items they observe within the broader enterprise that they are monitoring. A particularly important area of information exchange is that of terminology, which can vary between nations and even between facilities.

51. Lower-level information exchange may also be required since daily operations may impact upon the verification process. For example, Inspectors might take some reassurance in understanding operational activities, which may be as simple as emergency procedures for instance, even if they are not formally part of the verification regime. Such understanding may help to provide confidence that activities other than those declared are not taking place.

52. The UKNI experience suggests that information exchange, including but not limited to formal declarations, should be sufficiently *consistent* and *comprehensive* to meet Inspector needs while respecting Host national security concerns and the non-proliferation obligations of both parties – as well as being *complete* and *correct* (within the context of the Treaty). Given that the validity of operational details for a military nuclear complex is time-bound, regular reporting or updating might be necessary; and information exchange should thus also be *timely*.

53. This does not mean that the UKNI advocates the sharing of large amounts of nuclear weapon-related data, or information about the protective security arrangements for fissile materials and weapons stockpiles, or indeed any information superfluous to the aims of the declaration being verified. On the

contrary, given the large amount of data that the Host Party may be called upon to release, there is a duty on all Parties involved to consider carefully exactly what is needed and why that is the case.

Trust and confidence

54. Trust and confidence are not synonymous. States could maintain a high level of trust in each other to do something and yet have very little confidence in their own ability to detect a change in the behaviour of the other. Conversely, States may trust each other very little and yet maintain high confidence in their own ability to detect if the other is not doing what is expected. For effective verification of nuclear warhead dismantlement, the verification regime must be capable of generating high confidence regardless of the level of trust between the parties.

55. Factors which have tended to build inspecting team confidence throughout the UKNI exercises have included: successful isolation by the inspecting team of the Treaty Accountable Items and maintenance of chain of custody over them; knowledge of facility operational processes which either involve Treaty Accountable Items or have the potential to directly impact upon Treaty monitoring activities; and proactive attempts by the Host to facilitate inspection aims. On the other hand, ambiguity or inconsistency in information provided by the Host has tended to degrade Inspector confidence.

56. Although Host-Inspector familiarity and consistency of information are not the same as confidence – and indeed may lead to one party mistaking the trust they have built in the other as confidence in the process, they can help to build confidence because any deviations from expectation act as an alert of potential non-compliance. This approach to verification involves using a structured, systematic approach to demonstrate that the declaration is the only plausible explanation for the evidence observed. A large amount of contextual information may need to be provided by the Host Party for this approach to be useful.

57. Central to building true confidence in the technical aspects of verification is ensuring that all data from equipment are genuine. Building and maintaining confidence in verification equipment is therefore a vital component of building confidence in the verification regime as a whole. This is a complex problem, as achieving authentication of equipment to both parties' satisfaction and maintaining chain of custody over the equipment once authenticated are elaborate and time-consuming processes.

Conduct of inspections

58. The UKNI collaboration has reaffirmed that it is indeed possible to facilitate the access of foreign personnel, including personnel from NNWS, into nationally sensitive facilities – in this case real and simulated nuclear weapon-related facilities – without compromising national security or the non-proliferation obligations of either Party.

59. For the benefit of both Host and Inspecting Party, a clear set of aims and objectives are required when planning a visit to any specific location. Development of the plans may require a substantial amount of time and entail substantial information exchange by Treaty partners.

60. The planning and development process should ultimately result in a verification protocol and procedures that set expectations for both sides on how to conduct tasks and meet the objectives of the inspections in a mutually satisfactory manner. It is unlikely that ad hoc visits will be particularly valuable for verification purposes because extreme caution on behalf of the Host may require significant restrictions to be placed upon the visits. Although it is unreasonable to expect that every detail can be planned, in general Inspectors should not expect to have to undertake substantial negotiations at the point of inspection, and the rights and responsibilities of both Parties should be well-defined through agreed procedures. However, human interaction at the working level regarding on-the-ground discussions between both Parties about unforeseen circumstances can help foster mutual trust.

61. In order to allow inspection activities to take place at all, the host is likely to need to make changes to existing work processes. Because such processes generally are tightly controlled for safety and security reasons, any need for changes must be resolved as part of the detailed verification protocol negotiations. Changes may take considerable time to implement and may require the consent of domestic regulators before they can be finally agreed.

Development of verification technologies

62. Since different arms control Treaties will have different aims and objectives, it follows that generic technical solutions developed without a particular context in mind may not be readily deployable in practice. Deployment constraints – on the ability to use equipment in sensitive areas, for example, or the amount of time that technical equipment takes to set up or operate – may limit the effectiveness of some technical solutions, or even render them unusable. Nevertheless, there is value in attempting to apply generic solutions to specific scenarios for research purposes; this is an effective way of identifying challenges for the deployment of different technologies under those specific circumstances, and may also suggest mitigation strategies to researchers.

63. A further challenge to the design of generic technical verification solutions is the requirement for all Parties to the relevant Treaty to be content that the equipment in question performs only those tasks it is expected to perform under the verification protocol, and nothing else. The risks to the verification process that an authentication process should mitigate may evolve as verification procedures are developed, and so cannot be determined in isolation from the protocol.

64. The UKNI Information Barrier project has explored this problem in some detail, using jointly designed technology to explore the limits of what can be achieved for that particular system. While further work remains to be done in this area, we believe that a joint design process can help ensure confidence between Treaty Parties, and that this process should involve generation of a thorough design

specification, including agreement on the data that should be collected, the analyses to be performed, and all aspects of hardware and software implementation. The design requirements should consider the whole lifecycle of the technical solution, including the constraints in deployment and elsewhere imposed by the verification protocol and Host safety and security requirements. Hardware and software authentication methods, both procedural and technical, would therefore be useful and non-proliferative subjects that NWS and NNWS alike could explore to advance this field.

VII. Conclusions

65. The UK-Norway Initiative has, since its inception in 2007, served as exemplar of international cooperation on nuclear weapon dismantlement verification. It is the first such collaboration to involve a NWS and a NNWS working together, and it has paved the way for further broadening of nuclear weapon verification research to NNWS. The UKNI has made progress on the development of jointly trustable equipment; tested inspection procedures for specific tasks under 'Managed Access' arrangements in nuclear facilities; and researched factors influencing the outcome of inspections in nuclear weapon verification. The Initiative has also involved a significant outreach component, with participants from a number of other States attending UKNI research exercises and briefings.

66. Through this work, UKNI perspectives on nuclear warhead verification and the associated challenges have evolved. The Initiative started with a technical focus, looking to develop specific technical solutions that could work in a 'warhead dismantlement' environment and understanding how to allow international Inspectors access into sensitive facilities. Through projects designed with these goals in mind, it has become increasingly evident that solutions will be highly dependent on the context in which verification takes place. Whether or not verification is possible depends upon the aims and objectives for the verification process and the limitations that are placed on access to information, as well as on the purpose of the underlying Treaty. A verification regime must be considered as a holistic

system, with numerous elements – each of which may be weak by itself – combining to deliver solutions acceptable to all parties in terms of building confidence and preventing nuclear proliferation. The UKNI has therefore started investigating contextual factors, as they will determine the effectiveness of the technical solutions that the Initiative still endeavours to develop.

67. Central to the achievements of the UKNI has been our ability, as a NWS and a NNWS, to work constructively in partnership on the complex issues that nuclear weapon dismantlement verification presents. Norway and the UK, mindful of our obligations under the NPT, have entirely avoided activities that might risk transfer of proliferative information – and yet the UKNI has been able to make concrete progress, as this Working Paper demonstrates. We therefore reiterate our strong belief that there are no *a priori* barriers to collaboration between NWS and NNWS, and encourage others to examine what contribution they may be able to make towards nuclear weapon verification research in other, similar collaborations.

68. In order to understand the restrictions that could be placed on the inspectors and the verification activities they might seek to conduct in nuclear weapon facilities, we suggest that NNWS look to experts from their own sensitive facilities, explosives facilities, and nuclear material facilities for advice. In many cases these restrictions are likely to be similar, though not identical, to those present in NWS nuclear weapon facilities. This means that many States are in a position to prepare themselves, to some extent, for the likely constraints they might face in nuclear arms control verification activities.

VIII. Future work

69. The United Kingdom and Norway will continue to cooperate on issues related to the verification of nuclear weapons dismantlement. Over the next NPT review cycle, the UKNI intends to deepen the understanding of the use of inspection equipment, particularly Information Barriers, by further

investigating issues related to trust in technology and the usefulness of measurements in specific verification contexts. Furthermore, the Initiative will look to build on the success of the six trust and confidence student exercises run to date by conducting further research, education and outreach activities. In this way, the UKNI will work towards the mutual goal of developing practical verification solutions for future nuclear disarmament measures.

70. To date, the UKNI has approached discrete aspects of nuclear warhead dismantlement verification, focusing its efforts on Information Barrier development and Managed Access issues. Through this work, the researchers have repeatedly been reminded of the importance of understanding the context in which verification is to take place. The next programme of work will take this lesson into account and will consider verification aims and objectives more broadly. The Initiative will conduct a series of activities aimed at studying the use of verification technologies and Managed Access techniques in more fully-realised settings, and, in case studies, provide deeper understanding of the application of the results so far. The UKNI will also seek to work with additional parties.

71. As detailed throughout this Working Paper, there is considerable scope for further work in order to advance technologies and procedures for nuclear arms control verification. The UK-Norway Initiative only covers a fraction of these topics. Much greater international effort and cooperation is required to achieve the ultimate objective of an effective nuclear weapon dismantlement verification regime. The United Kingdom and Norway encourage the international community to engage actively in pursuit of this goal and are ready to support other parties that may be considering contributing to global nuclear weapon verification research efforts. We continue to be willing to share openly our experiences and the insights which we have derived from them, and will aim to participate actively in future international verification research efforts. In this regard, we welcome the recent formation of the International Partnership for Nuclear Disarmament Verification, the members of which we hope will take forward areas of research identified as priorities in this Working Paper.