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The United Kingdom-Norway initiative: research into the verification of nuclear warhead dismantlement

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

Summary

Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons sets out, among other elements, that all parties to the Treaty, nuclear-weapon and non-nuclear-weapon States alike, undertake to pursue effective measures relating to arms control and disarmament. Establishing effective verification measures will be an important precondition for fulfilling the goals of article VI. The United Kingdom-Norway initiative (with the non-governmental organization VERTIC (Verification Research, Training and Information Centre) as an independent observer) has explored activities in line with these obligations, with both parties mindful of their roles and obligations under international agreements and national regulations.

This report details the outcome of three years of collaboration between experts from Norway and the United Kingdom 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 presents significant technical and political challenges to both parties.

The report outlines the two main project areas, introducing briefly the aims and direction of the information barrier project but focusing primarily on the planning, conduct and evaluation of the managed access and monitoring visit exercise held in Norway in June 2009. It details the lessons learned during the course of the work and in its conclusions highlights the key findings and possible areas for development, including giving consideration to the potential role of the non-nuclear-weapon States. Finally, an insight is given into the possible future direction of study for the United Kingdom-Norway initiative, while the opportunity is taken to encourage the wider international community to make its own contributions to the ultimate objective of an effective nuclear weapon dismantlement verification regime.

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I. Introduction

1. Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons sets out, among other elements, that all parties to the Treaty, nuclear-weapon and non-nuclear-weapon States alike, undertake to pursue effective measures relating to nuclear arms control and disarmament. Establishing effective verification measures will be an important precondition for fulfilling the goals of article VI.

2. In a future verification regime for nuclear warhead dismantlement, inspecting parties are likely to request access to highly sensitive facilities and weapon components. Such access will have to be managed carefully by the hosting party to prevent the disclosure of sensitive information, both in compliance with the Treaty and in consideration of national security. At the same time, it will be incumbent on the inspectors not to gain proliferation-sensitive information.

3. The United Kingdom-Norway initiative is an ongoing collaboration between a nuclear-weapon State and a non-nuclear-weapon State 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 presents significant technical and political challenges to both parties. 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 nuclear-weapon State and a non-nuclear-weapon State on the issues faced by the other party
- To promote discussion on how a non-nuclear-weapon State could be involved in a nuclear arms control verification process.

4. This report presents the outputs from the technical cooperation during 2009, including an exercise held in Norway in June 2009, and builds on the work presented to the meeting of the Review Conference Preparatory Committee held in May 2009.

II. Background

5. At the 2005 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, the Government of the United Kingdom expressed an interest in exploring opportunities for interchange with other Governments and State organizations in the field of nuclear arms control verification. In late 2006, this led to representatives of the Norwegian Radiation Protection Authority (NRPA), the United Kingdom Ministry of Defence and the non-governmental organization VERTIC instigating a technical exchange between the United Kingdom and Norway in this field.

6. Early in 2007, representatives from four Norwegian laboratories, the Institute for Energy Technology (IFE), the Norwegian Defence Research Establishment (FFI), the Norwegian Seismic Array (NORSAR) and the Norwegian Radiation Protection Authority (NRPA), met with representatives from the United Kingdom Ministry of Defence, the Atomic Weapons Establishment plc (AWE) and VERTIC to

discuss potential cooperation on matters related to the technical verification of nuclear arms control. The Norwegian researchers were particularly interested in investigating how a non-nuclear-weapon State could play a constructive role in increasing confidence in the nuclear disarmament process of a nuclear-weapon State. It was agreed that an unclassified exchange within this field of research was feasible and that a programme of work should be developed. It should be noted that this is the first time that a nuclear-weapon State and a non-nuclear-weapon State have attempted to collaborate in this field of research. Under this initiative, two areas of research have so far been undertaken: information barriers and managed access. An account of this research can be found in sections III and IV below.

7. In its simplest state, an information barrier takes data from a measurement device, processes the data relative to predetermined criteria and provides a pass/fail output. Crucially, the information barrier must prevent the disclosure of sensitive measurement data to "uncleared" personnel. Information barriers are an important concept when considering future inspections, as inspectors would not be given unrestricted access to nuclear warheads; such access would breach the mutual non-proliferation obligations of the Treaty on the Non-Proliferation of Nuclear Weapons, as well as reveal national security-sensitive information. In 2007, the United Kingdom and Norway therefore embarked on the joint development of a robust, simple and relatively inexpensive information barrier system capable of identifying radiological sources.

8. Managed access is the process by which "uncleared" personnel are given access to sensitive facilities, or supervised areas, under the terms of an agreed procedure or protocol. A managed access familiarization visit took place in Norway in December 2008, allowing an "inspecting party" (the United Kingdom taking the role of a non-nuclear-weapon State) to become familiar with the mock-up facilities controlled by the "host party" (Norway taking the role of a nuclear-weapon State) and to prepare for a follow-on monitoring visit. The conduct of and outcome from the familiarization visit was the subject of a presentation given on the margins of the 2009 meeting of the Review Conference Preparatory Committee. The follow-on managed access monitoring visit exercise was held at the mock-up nuclear weapon dismantlement facility in Norway in June 2009. Two jointly designed information barrier prototypes were tested during the monitoring visit exercise; this was the first field test of the information barrier technology developed as part of the United Kingdom-Norway initiative.

9. This report to the 2010 Review Conference introduces briefly the aims and direction of the information barrier project but focuses primarily on the planning, conduct and evaluation of the monitoring visit exercise.

III. The information barrier development project

10. An important part of the cooperation between the United Kingdom and Norway in establishing a system for nuclear disarmament verification has been to design and build an information barrier system. Such systems are intended to be used by the inspectors to verify if sealed containers hold treaty-accountable items or not. Used in combination with other inspection techniques, an information barrier system is a tool for maintaining a chain of custody and to verify that the disarmament takes place in accordance with the declaration by the host country. The

use of an information barrier system enables the parties to meet the requirements of the Treaty on the Non-Proliferation of Nuclear Weapons and prevents disclosure of national security-sensitive information.

11. On the basis of a joint design, the United Kingdom and Norway have built two prototypes of the information barrier system, one in the United Kingdom by AWE and one in Norway by IFE and FFI. The system consists of a germanium detector and an electronic unit. The electronic unit records the detected gamma-radiation energies and runs a specially designed software code to determine if these recorded energies correspond to the declared type of radioactive material. The outcome of the process is either a green light indicating the presence of the declared type of radioactive material in the sealed container or a red light indicating the absence or insufficient quantities of this material. No other information is available from the electronic unit, and all collected information is deleted immediately after the result has been presented. As the output is only a simple coloured light, the joint design of the system is essential to ensure that both parties have confidence in the validity and accuracy of the result gained.

12. The information barrier system is a relatively low-cost, lightweight battery-powered system that can be easily transported and used in the field. The electronic unit is built from standard commercially available electronic components and is designed to be easy to inspect for any unauthorized changes. Prior to use the host can also easily substitute any of the modular components at the inspector's request. These modular components can then be thoroughly checked by the inspecting party for any alterations to increase confidence in the authenticity of the information barrier system. Indeed, even after use all modules except the data processing module could be available for further inspector checks.

13. The software codes in the United Kingdom and Norwegian prototypes were designed to detect a cobalt-60 isotope that was used in the mock-up nuclear weapon built for the monitoring visit exercise in June 2009. Both prototypes were thoroughly tested according to an agreed test programme prior to the monitoring visit exercise, and both were used successfully during the exercise.

IV. The managed access project

14. The first stage in the United Kingdom-Norway investigation into managed access was the creation of a framework for the conduct of practical exercises. This framework was developed by a joint United Kingdom-Norway planning team, with VERTIC acting as an independent observer. The core element of the framework was a hypothetical treaty, and its associated verification procedure, between two hypothetical countries, the "Kingdom of Torland", a nuclear-weapon State, and the "Republic of Luvania", a non-nuclear-weapon State. In an initial declaration, Torland stated its intention to dismantle its 10 remaining Odin class nuclear weapons (gravity bombs). Torland invited Luvania to verify the dismantlement process for one of these weapons. The verification procedure allowed for the Luvanian inspectors to undertake a familiarization visit to Torland's nuclear weapon complex and to subsequently carry out a monitoring visit to the same facilities to verify the dismantlement of one Odin class bomb. The dismantlement would be

considered complete once the Odin pit[1] had been placed in a monitored store. The exercise was designed to have a broad enough scope to provide an overview of the whole dismantlement and verification process.

15. The key objective for Luvania was to establish confidence in the declaration made by Torland with regard to the treaty-accountable item[2] and to demonstrate, to the satisfaction of both parties, a chain of custody through the dismantlement process. Luvania, as the inspecting party, would produce an inspection report in accordance with the verification procedure. The key objective for Torland was to demonstrate compliance with its obligations under the treaty while protecting national security and proliferation-sensitive information.

16. Several steps were taken during the planning stages of the managed access exercises to minimize the risk of proliferation. Initially, and continuously during the work, each of the parties assessed its roles and obligations related to articles I and II of the Treaty on the Non-Proliferation of Nuclear Weapons and implemented several measures:

- For the purpose of the managed access exercises, it was decided that the United Kingdom and Norway would switch roles. Norway would play the nuclear-weapon State while the United Kingdom would play the non-nuclear-weapon State. This also gave the participants the opportunity to explore the problem from the other side's viewpoint
- It was decided that the exercises would take place in Norway
- Although the exercise play was based on a framework involving "the Odin class nuclear weapon", the actual object used during the notional dismantlement process was based on a cobalt-60 radiological source
- The development of Torland's "atomic weapons laboratory", where the managed access exercises took place, was undertaken by means of discussions of a generic facility model comprising simple, logical building blocks which might conceivably be present within any nuclear weapon complex.

17. The joint United Kingdom-Norway planning team, with VERTIC as an independent observer, has worked since 2007 to develop the exercise scenario and supporting infrastructure, including the mock-up facilities in Norway. The planning team's particular aspiration was that the exercise should provide opportunities:

- To consider the level of cooperation that would be required between the two States parties (non-nuclear-weapon State and nuclear-weapon State) for the successful conduct of the inspection process
- To gain an understanding of the complexities and issues which hinder flexibility on the part of both parties
- To discuss the level of inspector/host confidence in the inspection process
- To test relevant technologies and procedures.

[1] The pit is the notional fissile component within the Odin nuclear weapon.

[2] The treaty-accountable item was the Odin pit.

V. The monitoring visit exercise

A. Facilities and timeline

18. Prior to the monitoring visit, Luvanian inspectors visited Torland's "atomic weapons laboratory" to familiarize themselves with the facilities (see figure below), the level of access, access controls and the timeline for the dismantlement. During this familiarization visit, broad agreement was reached in terms of the permissible inspection activities and the control measures which would be instigated by the host.

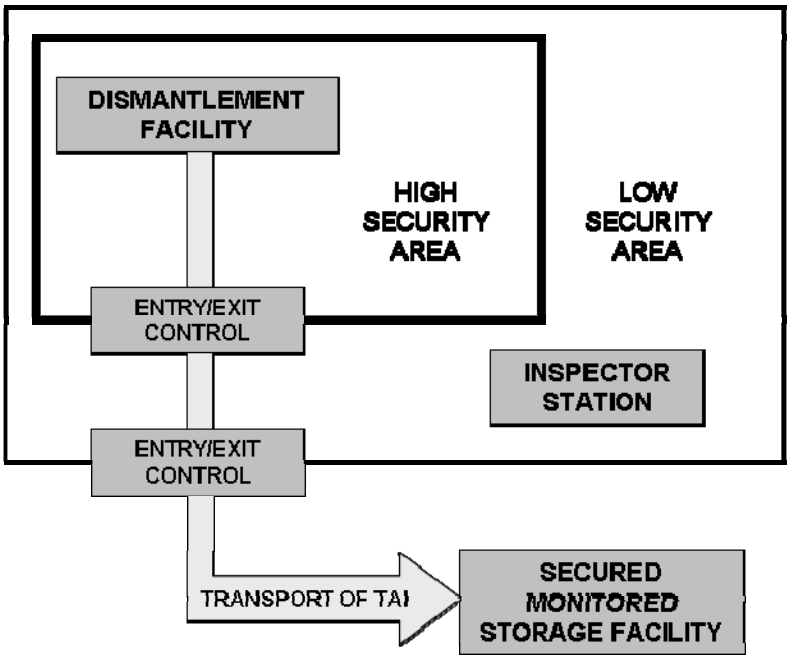
19. The Odin weapon was dismantled in stages in a process that took several days to complete. The inspectors were presented with the containerized treaty-accountable item at agreed points in this process; each point involved the use of a different sealed container. At the end of each day, the item was stored in an interim storage area. This storage area was secured so that the inspectors were confident that no tampering or diversion activities had occurred. At the end of the dismantlement process, the treaty-accountable item was transported from the dismantlement facility to a secured monitored storage facility (see figure).

20. The inspectors were provided with an "inspector station" located within a low-security area (see figure). Within this facility restrictions on activities were minimal, allowing the inspectors to pursue negotiations, review documentation, write reports and perform data analysis.

21. At the beginning of each day, the inspecting party and the host party met within the inspector station to review the facilities and operations scheduled for that day including the dismantlement and inspection activities to be performed. The inspectors were then taken through an entry/exit control point into the high security area (see figure) where the host party deployed a number of managed access techniques to ensure that the inspection activities did not breach health and safety regulations, disclose proliferative information or reveal information related to national security.

22. At the end of the inspection process, Luvania produced a report commenting on the degree to which the monitoring activities had demonstrated Torland's compliance with the initial declaration and its level of confidence in the overall chain of custody. Torland responded with its observations on Luvania's report.

Torland's "atomic weapons laboratory"



Abbreviations: TAI, treaty-accountable items.

B. Host techniques for controlling inspection activities

23. The Torian host team deployed a number of tactics in order to handle security and inspection activities:

- Identity checks before and during the visit
- Security briefings
- Change of clothing and metal detector checking
- Escorting and guarding
- Shrouding and exclusion zones
- Host control of equipment and measurements
- Documentation and information control including numbered note pads.

24. Torland requested a short curriculum vitae for each of the Luvanian inspectors prior to the monitoring visit in order to (notionally) undertake initial security checks. This information was then checked against proof of identity each time the inspectors passed from the low-security to the high-security area.

25. Torland gave security briefings to ensure that the inspectors understood the security procedures to be employed during the visit. These sessions allowed time to answer any questions and negotiate any points of contention.

26. Torland ensured that Luvania could not carry any covert monitoring devices during the facility-based inspection activities by requesting that "contraband" items

(such as mobile phones or watches) be surrendered prior to taking the inspectors into the high-security area. Torland confirmed that all such items had been handed over by asking the inspectors to (notionally) change into clothing provided by Torland and by using a metal detector to perform a search.

27. Within the high-security area, escorts and guards were assigned to the Luvanian inspectors to ensure that they only performed agreed activities within designated areas. Torland used shrouding to conceal items which could provide sensitive or proliferative information. Exclusion zones were marked to identify areas prohibited to inspectors.

28. Notionally, Torland ensured that the equipment used by the inspectors did not contain any covert monitoring features and did not measure parameters which would be considered sensitive or proliferative. In order to achieve this, all inspection equipment was notionally agreed, authenticated and certified for use within the facility prior to the commencement of the exercise. The equipment used within the high-security area was supplied by the host. It was agreed that Torland facility staff should undertake all measurement and sealing activities under Luvanian supervision.

29. The inspection process was documented and attested by both parties; the measurement data were held jointly until officially released by Torland for use within the inspector station. All numbered note pads and pens used within the high-security area were supplied by Torland. These were issued just before entrance into the high-security area and collected before exiting. Torland reviewed all notes to ensure that no sensitive information had been recorded.

30. Many of the above measures were primarily based on security concerns, however, health and safety was also an overriding consideration for the host party. Many areas within a nuclear weapon complex are subject to strict regulations and the host must ensure that these are followed during the course of the visit. Torland provided additional health and safety briefings along with appropriate protective and restrictive measures.

C. Inspection activities

31. The Luvanian inspectors deployed a number of techniques and processes to support the verification activities as agreed during the familiarization visit:

- Radiation monitoring
- Tags and seals
- Digital photography of the tags and seals
- Closed-circuit television cameras
- Information barrier system for gamma measurements
- Photography of inspection relevant items, in situ and with inspectors present
- Review of documentation relating to the Odin device, and visual observations and dimensional measurements of the Odin weapon and containers.

32. All necessary equipment was supplied by the host party to ensure compliance with health, safety and security requirements. The inspectors were permitted to use

their own equipment at the inspector station, but not inside the dismantlement facility. Authentication of host-supplied equipment was not carried out in the exercise. However, some of these issues were addressed in the information barrier project.

33. Prior to any activities being undertaken within the dismantlement facility, the inspectors needed to convince themselves of the absence of materials and sources which could impinge on the inspection activities. Radiation monitoring activities were undertaken using gamma and neutron count rate monitors supplied by Torland. The overall sweeping concept was designed to gain confidence in the integrity of the inspection activities. Once the inspectors had ensured that the area was clear, all personnel, equipment and containers were monitored in and out of the area. The only exceptions were sealed containers declared to contain the Odin weapon or its components. This procedure was repeated once the dismantlement was complete, to ensure that no treaty relevant materials had been left within the facility.

34. A hand-held gamma radiation monitor and a hand-held neutron monitor were supplied by the host party for the sweeping. The deployment of both gamma and neutron sweeps on containers made it harder for the host to shield diverted materials or covert sources. The sweeping activities were very time-consuming.

35. Tags and seals were used for three reasons: to be able to uniquely identify any containers with the Odin weapon or its components, to ensure that no containers had been opened and to ensure that during dismantlement no materials had been removed from the facilities. Tags and seals were applied to the inside of the facilities immediately after sweeping. The commercial tags and seals used were based on research undertaken in the United States of America and for the International Atomic Energy Agency. The method relied on the inherent tamper-indicating properties of the seals, with the inspectors adding unique random particulate identification tagging to each seal.

36. The tags and seals were verified by photographing the random particulate identification tagging. For the exercise, the tagging consisted of simple glitter supplied by the inspectors and randomly encapsulated in an adhesive. This was applied to the host-supplied seals in the inspector station shortly before use in the facilities. It is important that the inspectors be able to impose their own unique identifying feature, particularly if the seals are host-supplied, to ensure that the seals cannot be swapped. During the exercise, the images of the seals were taken to the inspector station to be compared with a blink comparison technique. Undertaking this in the inspector station allowed the inspectors to use their own software to ensure high confidence in the results.

37. Closed-circuit television cameras were deployed notionally at points of interest where the information, within the agreed field of view, was considered to be insensitive by the host. The cameras provided a direct visual confirmation that no personnel or material had entered or left the facility while the inspectors were not present. Examples include views of ceilings within dismantlement facilities and of exit doorways, which the host had agreed would not be used during the dismantlement activities.

38. The information barrier system was used to confirm that the initial container, declared to contain the Odin weapon system, had a gamma radiation signature compatible with the host’s declaration. After each stage of dismantlement, the

information barrier system was used to confirm that the container declared to hold the treaty-accountable item met this agreed signature. All other containers were then monitored with the non-barriered radiation detectors to confirm the absence of any radioactive material. Once a container was confirmed as empty of radioactive material, it could be removed from the facility. The container with the treaty-accountable item was sealed to ensure the further chain of custody.

39. Photographs of inspection-relevant items were taken to provide documentary evidence that the inspectors had carried out their inspections on site as agreed.

40. Some redacted documents containing a limited history of the Odin device with serial number, dates and signatures were provided by the host party. Prior to the dismantlement, a limited number of inspectors were allowed to see the outer casing of the Odin device. Some documents were provided by the host to show physical parameters and serial numbers which could be verified by the inspectors on the systems as presented to them. The collection of documents made available to the inspectors by the host was intended to provide further confidence that the item under verification was indeed an Odin system.

D. Strategy and negotiations

41. Neither party had developed a comprehensive strategy prior to the exercise, though both had elements in place. All of the participants understood that national security and non-proliferation commitments were an overriding consideration.

42. During negotiations, the Torian hosts were reminded that they had invited Luvania to inspect the dismantlement process. This, coupled with the non-reciprocal nature of the agreement, placed Torland in what was regarded as a slightly weaker negotiating position. However, as the exercise progressed the Luvanian team became more aware that their actions and conclusions would be the subject of scrutiny by the international community, increasing the pressure on the Luvanian inspectors to deliver what had been agreed.

43. A number of issues were subjects of negotiation: facility schematics, images of inspectors within facilities, physical measurements on the weapon itself, the use of open-source images, serial numbers and surfaces interfacing with seals. Even though both parties had considered that most issues were resolved by the end of the familiarization visit, it soon became apparent that a large number of details still required negotiated agreement before monitoring activities could proceed.

44. Torland’s negotiating stance allowed concessions to be made on points where national security or non-proliferation was not an issue. This fitted well with Luvania’s view of a cooperative process which inspired trust and confidence. As the negotiations progressed, and the Luvanian inspectors continued to request activities beyond the initially agreed scope, the Torland hosts began to adopt a firmer stance to Luvania’s demands.

VI. Lessons learned

A. Host perspectives

45. The exercise emphasized the key challenge facing the host party during any verification regime operating within a nuclear weapon complex: how to provide the inspectors with the opportunity to gather sufficient evidence, while at the same time protecting sensitive or proliferative information. The host will share in the responsibility to ensure that the verification regime has been applied comprehensively. The host will not want to be unjustly accused of hindering the inspection activities or indeed cheating.

46. Health and safety regulations will dictate some of the host's responses to inspector requests. State legal requirements may also restrict activities within explosive and radiation protection areas.

47. The host has to take care, when considering national security and proliferation concerns, that the information provided to satisfy individual inspector requests does not become sensitive when it is aggregated. The host might consider agreeing to requests "in principle" until all of the inspector requests have been collated.

48. The host will have to consider the impact of the inspection process on facility operations and available resources. By negotiating and agreeing on all aspects of the visit in advance, issues can be discussed and resolved. The host might consider it to be advantageous to take a more cooperative stance in the negotiation process, with a view to minimizing the amount of time within the facility and promoting inspector confidence in the verification process as a whole.

49. The escorting concept deployed during the exercise focused on controlling the inspectors. Both guards and facility staff were involved in escorting duties, although there was some confusion among the facility staff as to their responsibilities, as they also had to facilitate the inspection activities. It was clear that the Torian team did not have enough staff to support both the security escorting and the technical inspection activities. At times the inspectors outnumbered the host staff, giving some of the inspectors the opportunity to perform unsupervised measurements. Another concept would be to split the support to escorting and technical inspection with respect to activities, objects, equipment or sensitive areas. This might increase the number of facility staff required but would allow the escorts to study the agreements specific to their area of responsibility. If the facilities have limits on personnel numbers, this will have a significant impact on the number of inspectors allowed into the area and the rate at which they can therefore conduct their activities. Regardless of the concept deployed it will be essential that all staff are well drilled in the procedures required.

B. Inspection activities

50. The layout of a facility will either help or hinder radiation monitoring activities. Facilities which allow the inspectors to move around the outside of the area of inspection are desirable; facilities which could conceal cavities, such as heavily mounded buildings, will pose more of a problem.

51. Shrouded objects are an issue, particularly where the shrouding is hiding tooling which will be used in the dismantlement process — these items cannot be sealed. Unsealed shrouded objects could be hiding shielded covert sources or shielded containers to be used during material diversion. This is an issue that requires further thought.

52. The tagging and sealing process highlighted a number of issues. Over time some of the seals started to peel off the painted walls. This indicates how important it is to consider the surfaces that the seals will be applied to, not just the seals themselves. While it was possible to place the seals in almost any location, taking images of the random particulate identification tagging was difficult in awkward positions. Over an extended period of time, any vulnerability could be exploited by the host, who after all has all the resources of a State party. If the seals were only going to be relied on for a short time, the deployed solution might be adequate; for longer periods, new ideas must be considered. The large number of seals proved to be time-consuming to deploy and evaluate, while the vehicles proved almost impossible to seal to the inspectors' satisfaction.

53. The blink comparison process proved to be very effective at verifying random particulate identification tagging, but viewpoints differ in terms of accepting "human factors" in the evaluation of data. The automation of the comparison technique is certainly an area for consideration.

54. The concept of closed-circuit television would need further consideration if it were to be deployed within a nuclear weapon complex. However, the exercise has shown that closed-circuit television can be usefully deployed in situations without significant security or proliferation risks, such as the monitoring of ceilings and of entrances unused during dismantling activities.

55. The inspectors felt that to effectively deploy chain of custody measures, the team needed to give greater consideration to the threat and the vulnerabilities. Such an assessment would form part of a risk/benefit analysis where the inspectors would consider the threat, the likelihood of the scenario occurring and the confidence levels associated with the deployment of a particular concept. The inspectors commented that it would have been better to have stepped back and considered the area more thoroughly rather than rushing in to complete the work. It should be noted that schematic drawings are unlikely to have sufficient three-dimensional detail to satisfy all the requirements of the inspectors in developing comprehensive chain of custody measures.

56. Radiation monitoring, sealing and the deployment of closed-circuit television cameras have to be considered as parts of a unified strategy for securing an area. Overall, it is the consideration of the entire verification system that is important rather than each element in isolation. The inspectors will always be looking for anomalies relative to the regime as a whole. The concept of multiple layers of protection proved to be particularly important.

C. Joint experiences

57. Host/inspector interactions became friendlier as the work progressed. This phenomenon has been observed in other exercises, as well as in real inspections, and

can be instrumental in building trust. However, this does need to be managed so that professional detachment is maintained.

58. The exercise did emphasize the importance of considering the movement of information and equipment across areas with differing security restrictions. It was deemed very important for the inspectors to have access to an inspector station where they could work with a minimum of restrictions (this includes the use of equipment to record and analyse inspector observations and measurement data). This inspector station would need to be outside all host sensitive facilities. The movement of information and equipment between the sensitive facilities and the inspector station is a complex issue that should not be underestimated. All such transfers will need host approval and be under host control. For example, written notes on host-supplied paper or photographs of a seal are likely to be approved, while computers, electronic equipment and complex data files are unlikely to gain approval. Inspectors must carefully consider such issues when designing their verification approach.

59. The Luvanian inspectors felt that they had learned a lot from carrying out the inspections in the field as it allowed them to test out concepts and identify weaknesses. It is all too easy to lose perspective when working purely within a controlled laboratory setting.

60. The remit of the verification regime is driven by the host's declaration as the inspectors can only confirm what has been declared. The choice and capabilities of the equipment will then need to reflect this information. For example, the information barrier system cannot incorporate a mass threshold if no indication of mass has been given. The problem for the host is what the declaration can say given the non-proliferation and security requirements. The host will need to perform a rigorous risk assessment considering proliferation and security concerns with respect to the overall potential gains in inspector confidence. This is both a technical and political matter for further consideration.

VII. Inspector/host confidence

61. The Luvanian inspector team wrote an inspection report which was issued to Torland for comment. In summary, the inspectors made the following observations:

- The inspectors were able to deploy all the techniques deemed necessary to sustain an unbroken chain of custody of the item declared by Torland as the treaty-accountable item, from start to finish of the inspection
- The information barrier system was successfully deployed four times during the inspection process — the presence of the notional weapons-grade plutonium (in reality, radioactive cobalt) was confirmed each time
- The cooperation from Torland was exemplary
- As a result of the above, the inspection team was able to confirm with a high degree of confidence that the objects declared as the Odin weapon, and its associated containers, moved through the declared dismantlement process
- Further scientific measurements and documentation indicating provenance could, in future dismantlement processes, provide greater reassurance that the object was the Odin system.

62. The Torian host team added the following observations to the inspection report:

- Torland was satisfied that its national security had not been compromised and that non-proliferation obligations had been observed at all times
- Torland felt that Luvania's requests for additional information had been reasonable and acceptable
- Torland agreed that further technological development was necessary, particularly in the area of information barrier measurements, in order to confirm the identification of the Odin system.

63. Despite obvious weaknesses in the verification technologies and procedures and in the host security arrangements, both teams had high confidence that they had met their obligations.

64. The host party's assessment of national security and proliferation issues cannot always be backed by explicit reasoning. Inspector and host awareness of these issues will affect the possibility of obtaining the best possible outcome.

65. Several points were highlighted where the host might have considered diverting materials or performed a spoofing scenario. However, as these opportunities could not have been predetermined and were unlikely to be repeated, would the host risk taking advantage of them? Overall, the inspectors need to take a rigorous, but risk-based approach — the inspectors will never be 100 per cent confident.

66. None of the verification measures used could confirm that the object was an Odin class weapon as declared. The information barrier measurements, along with the documentary evidence, built confidence but were not definitive proof. It was not the intention of this series of exercises to solve this "initialization problem"; however, it has highlighted the issue.

67. If the international community is to have a discussion on the issues of inspector/host "confidence" or "trust", ideally some form of metric for these parameters needs to be developed.

VIII. Conclusions

68. As stated earlier, article VI of the Treaty on the Non-Proliferation of Nuclear Weapons sets out, among other elements, that all parties to the Treaty, non-nuclear-weapon and nuclear-weapon States alike, undertake to pursue effective measures relating to arms control and disarmament, and their verification. Establishing effective verification measures will be an important precondition for fulfilling the goals of article VI. The United Kingdom-Norway initiative (with the non-governmental organization VERTIC as an independent observer) has explored activities in line with these obligations, with both parties mindful of their roles and obligations under international agreements and national regulations.

69. This collaboration in the field of verification for nuclear arms control has resulted in the successful delivery of two managed access exercises: a familiarization visit exercise, which took place in December 2008 (reported previously), and the follow-on monitoring visit exercise, which took place in June

2009. This is the first time that a nuclear-weapon State and a non-nuclear-weapon State have attempted collaboration in this field of research.

70. The broad scope of the monitoring visit scenario provided the participants with a global view of how all of the elements of the verification regime would fit together in order to support the inspection process. A number of managed access concepts were deployed in order to control inspection activities within the facilities. The exercise process emphasized the importance of controlling the movement of information, equipment and personnel across areas of differing security restrictions and the need to improve on procedures supporting this process.

71. A variety of inspection techniques were deployed in order to create a multilayered approach to the chain of custody and overall inspection activities. It was noted that to effectively deploy these chain of custody measures, a rigorous risk assessment considering the potential threats and vulnerabilities needs to be undertaken. Radiation monitoring, sealing and surveillance technologies have to be considered in one unified strategy for securing an area prior to inspection activities. The practical experience from the use of these techniques highlighted many lessons; for example, the resource-intensive nature of seal deployment and verification demonstrated the need to investigate alternative approaches. The concepts of authentication, certification and chain of custody of inspection equipment were only played notionally; however, these aspects are recognized as being vital elements within a verification regime.

72. The jointly developed information barrier systems were successfully deployed throughout the exercise. The exercise remit for the information barrier system was to confirm the presence of (notional) weapons-grade plutonium. This alone would not be sufficient to give the inspectors confidence that the host had not cheated. Future proposed developments to the system include the ability to confirm material grade and perform a mass threshold measurement. The project will continue to look to incorporate the concepts of authentication and certification. It was felt that this technological concept would only ever be able to confirm that the measured attributes are consistent with the presence of a nuclear weapon, but would not be able to provide a definitive identification. This calls into question the ability of the inspecting party to initialize the verification process, in other words, to confirm that the item presented is indeed the declared nuclear weapon (known as the “initialization problem”). Attempts were made to compensate for this deficiency by requesting documentation related to provenance, but this will only have limited value unless it is linked to measurements and other supporting evidence.

73. The United Kingdom and Norway believe that it should be possible to maintain a chain of custody for nuclear warhead dismantlement to a high degree of confidence when the relevant technologies have been developed to the necessary level of functionality. The initialization problem is an ongoing issue which requires further consideration before a technical solution can be proposed.

74. As a result of the success of these initial programmes of work, the United Kingdom and Norway have identified many areas that warrant further research and development. Some of these will be addressed in our ongoing collaboration; however, greater international effort is required to resolve all of these major issues.

75. This technical exchange has shown that a nuclear-weapon State and a non-nuclear-weapon State can collaborate within this field and successfully manage

any risks of proliferation. It has been found that many of the underpinning issues can be posed in generic terms which would allow non-nuclear-weapon States to contribute to technological developments; the development of flexible, generic solutions means that the results could be tailored to support a number of future, "real-life" scenarios. The participants felt that the involvement of non-nuclear-weapon States would be vital in creating international widespread acceptance of, and trust in, a proposed verification regime. The United Kingdom found that the Norwegian participants brought a fresh perspective to the problems which challenged long-standing opinions and viewpoints.

76. Overall, it was felt that the exercises demonstrated that it should be feasible for a non-nuclear-weapon State to contribute to the chain of custody aspects of a verifiable nuclear dismantlement process. The initialization problem remains a fundamental issue that needs to be resolved and therefore the potential role for the non-nuclear-weapon State in this aspect of the process is unclear.

77. The safety and security of nuclear weapons and the subsequent dismantlement of these weapons are of concern to all countries, regardless of their status as nuclear-weapon or non-nuclear-weapon States under the Treaty on the Non-Proliferation of Nuclear Weapons. The importance of national security considerations within the nuclear-weapon States may not be fully realized or even acknowledged by the non-nuclear-weapon States, a fact that would easily lead to differences in understanding. The exercises demonstrated that the consideration of national security and proliferation permeates everything that the host party attempts to do, and therefore these issues interact with the whole of the verification regime. It was noted that health and safety regulations, and not just security, will dictate some of the host's responses to inspector requests.

IX. Future work

78. The United Kingdom and Norway are interested in continuing and expanding the research into both the areas of managed access and information barriers. It was proposed that the managed access project will initiate a series of targeted exercises picking up on specific issues highlighted during the recent familiarization and monitoring visits. This will bring both States even closer to a common understanding of the challenges inherent in such cooperative disarmament work.

79. The current information barrier is not yet a deployable system. The United Kingdom-Norway initiative plans to move the system towards the identification of grade as well as material presence; the exercises highlighted the need for the additional phase of development towards mass threshold measurements. It was noted that the complexity of the system has increased, and that trend is likely to continue as additional functionality is added. Conversations between the engineering and arms control communities must continue to ensure that any proposed solutions are simple, cost-effective and fit for purpose. Involving the wider group would ensure that the technical solutions fit with the development of trust and confidence. Ultimately the information barrier project must be peer-reviewed.

80. As detailed throughout this report, there is considerable scope for further work in order to advance technologies and procedures for nuclear arms control verification. The United Kingdom-Norway initiative only covers a fraction of these topics. Much greater international effort and cooperation are 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.