NuDiVe Exercise

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Report by the Evaluation Team

Contents

Summary of observations

1. The Nuclear Disarmament Verification (NuDiVe) exercise organised by Germany and France successfully tested, under many realistic conditions, a key step in an inspection process for multilateral verification of the dismantlement of a Nuclear Explosive Device (NED). An “inspection team" of experts from seven countries applied verification measures immediately prior to and following a notional dismantlement[1] of a NED to gain assurance of the non-diversion of fissile material. A “host team", representing the fictional inspected state of “Urania,” used managed access arrangements designed to prevent any disclosure of information that could pose a risk for proliferation of nuclear weapons or other sensitive information. Procedures followed in the exercise were prepared by the exercise organisers, building on inspection concepts and approaches developed by the International Partnership for Nuclear Disarmament Verification (IPNDV). An independent evaluation team observed the exercise. Preliminary observations from the exercise included:

a) The inspection team was generally satisfied that it had successfully applied the procedures to establish containment and surveillance measures to detect any diversion of fissile material or weapons components from the area where the notional dismantlement took place.
b) Evaluators and exercise participants consider that the exercise demonstrated that the IPNDV-developed inspection concepts and approaches on which the exercise was based are

1 Dismantlement refers to the physical process of separating special nuclear material from high explosives and other components.

sound. More work is needed to improve efficiency and effectiveness of the inspection process, including steps to ensure that strategic inspection objectives are not lost when implementing the detail of an inspection.

c) Evaluators and exercise participants identified ways in which detailed inspection procedures used in the exercise should be refined and augmented, for example, redesigning some procedural steps so that inspection effort and resources can be more clearly focused on critical inspection objectives.
d) Inspection equipment employed in the exercise demonstrated value, with knowledge gained by this deployment of technical tools providing ideas for future development. Evaluators and exercise participants identified areas for further work.
e) The inspection scenario developed by the exercise organisers, and the facilities offered by the Jülich Research Centre, added realism to the exercise. Useful lessons were learned on how to enhance the value of gameplay in future exercises, including to ensure activities are best aligned with the strategic objectives of an inspection.
f) Participants highlighted the value of practical exercises in future work on nuclear disarmament verification, particularly for developing, testing, and refining IPNDV concepts and approaches, and in building and maintaining the expert capacity needed to advance this work.

Recommendations to IPNDV partners

2. Future work by IPNDV and its partners can benefit from many of the lessons identified through the NuDiVe exercise. The evaluation team highlights the following points raised in this report:

Equipment and technology

i. Significant work needs to be done not just to develop useful technologies, but also to produce systems that are functional and reliable in the context of an inspection (paragraph 45), including a CCTV system (paragraph 11) and portal monitor (paragraph 14).
ii. Evaluators and exercise participants offered suggestions for improving the design of handheld detectors that may be used in inspections (paragraph 15).
iii. The sealing kit could be improved (paragraph 16).
iv. Tools to facilitate communication between and within teams could be further developed (paragraph 17).
v. Discussion is needed on ways to mitigate impacts to inspection effectiveness and inspector wellbeing that may result from the use of Tyvek inspection suits (paragraph 18).
vi. Some lessons on facility design were identified (paragraph 19).
vii. Information barrier techniques may be needed for the radiation detection technologies used in facility design checks to prevent disclosure of background count rates (paragraph 20).
viii. Work is required on approaches to confirm that an item is non-nuclear without divulging sensitive information (paragraph 22).

Inspection procedures

ix. Evaluators formed a view that reliance on following detailed procedures came at a cost to independent and strategic thinking for both inspection and host team members (paragraph 26).

x. Better prioritisation of inspections tasks may have enabled adequate assurance, but with less effort, if a holistic approach to risk could be taken. IPNDV should discusses how a systems approach could be applied to the design of containment and surveillance (C&S) systems (paragraph 28).

xi. IPNDV should discuss the kinds of information that should be available to inspectors for their planning, including planning that may be conducted prior to the arrival on-site of an inspection team (paragraph 29).

xii. To facilitate a shift from the very conceptual work of IPNDV to the very practical requirements of an inspection or exercise, IPNDV should consider the nature and structure of guidance that would be needed to support a multilateral inspection and that facilitates a balancing of the interests of participants (paragraphs 32, 33).

Interaction between the inspection and host teams

xiii. A perception of power imbalance may be inevitable for inspections at high security sites, but could colour the judgements that inspectors make. IPNDV could consider ways in which this problem could be managed (paragraph 37).

xiv. Early and regular discussions between teams (both formal and informal) about their respective objectives in an inspection should promote a cooperative culture (paragraph 40).

xv. A future exercise (or pair of exercises) might alternate host and inspector roles in order to promote non-adversarial outcomes (paragraph 40).

Lessons for future exercises

xvi. Playing teams should be more fully trained ahead of an exercise. IPNDV should consider how it may establish a cadre of experts with training in techniques and methodologies relevant to nuclear disarmament verification. An early step in this direction could be for IPNDV to prepare a list of relevant competencies for which a training program could be developed for a future exercise (paragraph 53).

xvii. An active and independent control team is useful for managing the flow of an exercise and to help to put things back on track if necessary (paragraph 56).

xviii. Future exercise organisers should consider additional guidance for playing teams so that each can work to a coherent strategy (paragraph 58).

Overview of the NuDiVe Exercise

3. The overarching goal of NuDiVe was to verify that the concepts developed by IPNDV for verification of the dismantlement of a NED (as tested by the exercise) are effective, efficient and potentially usable. The exercise focused on the ability of the IPNDV-identified inspection approaches, procedures and technologies to provide assurance of the non-diversion of nuclear materials and other components during notional nuclear warhead dismantlement operations. In particular, the exercise focused on implementation of inspection approaches in steps 8.1, 8.3 and 8.4 of verification of NED dismantlement as developed by IPNDV within the 14 Step document developed during IPNDV's Phase II (see Box 1). Detailed inspection procedures were developed by the exercise organisers to implement the IPNDV-developed approaches.

Box 1. Key IPNDV-develop inspection approaches tested in NuDiVe

8.1) Confirm chain of custody for the item to be dismantled

- Prior to dismantlement, the inspection team checks tags, seals, and UIDs on each accountable item to be dismantled and if necessary reviews surveillance data for the item[2].

8.2) If needed to re-confirm consistency with declarations of each accountable item to be dismantled, an inspection team[3]:

- Observes and measure item attributes (mainly radiation measurements) to confirm consistency with declared verifiable characteristics; and/or
- checks against an applicable template for the item.

8.3) Confirm that no SNM or HE[4] is present in the dedicated dismantlement area prior to or following dismantlement

- The inspection team "sweeps" the area under managed access, using hand-held monitoring equipment to detect any SNM or HE.

8.4) Confirm that the only accountable items to enter or leave it are those which have been declared and that no SNM is diverted during the course of the dismantlement operations

- An inspection team:
  - Makes visual observations and/or applies portal monitoring and other applicable C&S measures to ensure that the declared NED and empty component containers are the only accountable items to enter or be removed from the dedicated dismantlement area.
  - Applies seals in the dismantlement area at potential diversion pathways
  - Checks host staff entering and leaving the dismantlement area by radiation monitors.

4. The scenario for the exercise focused on inspection activities at a notional multi-purpose facility, that is: a facility where various nuclear weapon-related activities take place, but where a designated location within a "controlled area" is used for verified dismantlement. All inspection activities, aside

2 There was no check of a UID or of prior surveillance data.
3 Step 8.2 was not exercised in NuDiVe
4 SNM: special nuclear material, HE: high explosive

from planning and data analysis, were conducted in the controlled area, which consisted of three rooms and an adjacent corridor.

5. NuDiVe was conducted as a gameplay exercise, with participants assigned roles in the following groups:

- host technical personnel, including Jülich staff supporting the exercise (blue shirt);
- host team, representing "Urania" (red shirt)
- inspection team, from a notional multilateral verification entity (black shirt)
- evaluation team (green shirt)

6. The NuDiVe exercise took place over five days. The first day and a half was for training of external participants in behavioural rules for, and technologies used during, the exercise; the final half-day was used for a post-exercise "hot-wash" discussion. For the remainder of the week, the host and inspection teams planned, discussed and conducted inspection activities independently, then jointly to reach agreement on daily activities. The inspection team prepared daily reports (to a notional inspectorate headquarters) describing its activities.

Evaluation process and methodology

7. The five-person evaluation team[5] observed all inspector-host interactions and most internal team discussions. Evaluators formed views based on direct observation of exercise activities, including in-game comments by many of the exercise players. Outside of exercise play, interviews were conducted with exercise organisers and team leaders, and all players completed questionnaires at the beginning and end of the inspection phase of the exercise. Comments during the post-exercise hot-wash were also noted. Table 1 contains the list of key questions that were developed by the evaluation team ahead of the exercise to assist with the evaluation process. Some lessons outside this framework emerged also.

Table 2. Key questions for evaluators

Target	Key Questions
a) Use and performance of inspection technologies	What do the technologies do well? What do they not do well?
	What are the gaps in technical capability and design?
b) Value of inspection approaches and procedures	What do the inspection approaches and procedures do well / not so well?
	Were the procedures easy to use and understand?
	To what extent were inspection approaches and procedures effective in confirming the object of the inspection? To what extent were inspection approaches and procedures efficient in minimizing the time and effort needed to complete the inspection?
	If applicable, how well were discrepancies resolved?
	How well did managed access measures related to proliferation risk and national security/safety work for the inspected state?

5 Malcolm Coxhead and Rob Floyd (Australia), Corey Hinderstein (NTI), Alicia Swift (USA), Ralf Straub (Switzerland)

c)	Interaction between the inspection and host teams	To what degree did security / safety measures impact conduct of the inspection?
		What matters needed to be negotiated "on the ground" and were the outcomes mutually satisfactory?
d)	Overall assessment of inspection activities	To what degree did the inspection activities provide confidence that state declarations were accurate? Detract from confidence? How close are we to inspection approaches and technologies that are technically and practically sound?
e)	Assessment of the exercise scenario design, venue and organisation for testing IPNDV and ideas	Was the exercise effective for testing IPNDV-developed verification concepts? What lessons are there for future exercises? Was the training on the procedures / technologies adequate to accomplish the exercise objectives? Was useful knowledge shared between the NNWS and NWS participants?

Evaluation results: Use and performance of inspection technologies

8. The following inspection-specific technologies and equipment were used during NuDiVe (along with various auxiliary items, e.g., for note-taking):

- sealing kit (transparent bag, handheld cameras, camera batteries and SD memory cards, adhesive seals, reflective particle matrix)
- portal monitor units and associated gamma and neutron test sources
- CCTV cameras
- computer terminals (laptops) for portal monitor and CCTV cameras
- neutron search detector
- handheld gamma detector
- handheld camera, camera batteries and SD memory cards
- SD flash memory for cameras and clear plastic vials for transfer from the controlled area
- tape measure and laser distance meter
- fixed-line telephone for communication between the controlled area and the inspection team's office
- high-density polyethylene (Tyvek) inspection suit, plus overshoes and latex gloves
- dosimeter and handheld contamination monitor (for health and safety purposes).

9. At the end of the exercise, the inspection team declared itself satisfied that it had been able to apply adequate C&S measures to detect any diversion of fissile material from the dismantlement area. In this respect, the technologies and equipment used in NuDiVe performed adequately. Although equipment systems such as the CCTV cameras and portal monitor systems are prototypes, and clear areas for improvement were identified, the value of such tools in an inspection was recognised by exercise players and evaluators. Inspectors used the sealing kit extensively and did not identify any failure of a seal that undermined their task.

CCTV

10. Exercise participants recognised the potential for CCTV monitoring as a useful element of a C&S system. That said, the inspectors considered it as a secondary layer in their C&S model. It was not practical for them to review all video to identify an event of concern, and access to video was requested only to investigate events observed in other ways. Confidence in CCTV during the exercise was undermined by the failure of a camera wall-mount and damage to the mounted camera when it fell.

11. For this exercise, four consumer-grade internet protocol video cameras were used and linked to a control terminal using WiFi. Although a practical choice for the exercise, evaluators (and organisers) noted that the use of WiFi, and some types of consumer-grade cameras, may not be desirable where data security and authenticity and system performance is critical. Evaluators and exercise players offered additional suggestions for development of an improved CCTV system:

- Additional CCTV cameras may be needed to maintain line of sight (there were blind spots in this exercise).
- Tools could be developed to make the review of video more efficient. These might be implemented using automated review software with image change detection.
- Synchronisation of CCTV clocks with those used with other equipment (e.g. portal monitors) may be needed.
- Evaluators observed that inspectors working in the controlled area sometimes struggled to monitor for any tampering with their unsealed equipment. If a CCTV viewer was available outside the controlled area, an additional inspector (under escort) could monitor that equipment, thus freeing inspectors working inside from an extra task. This could also simplify shift-change requirements.

Portal Monitor

12. Evaluators and exercise participants recognised that portal monitoring is a very useful technology for this type of inspection. An excellent portal monitor was available, but design refinements would be needed to make it fully suitable for use in a dismantlement inspection..

13. With respect to effectiveness of the system, some exercise participants did not feel that calibration tests were consistent with the operational environment in which they would be asked to perform during an inspection. Some noted that if the test sources for gamma and neutron detectors are stronger than the actual gamma or neutron emissions of a warhead, functionality testing will not be effective. There was also some concern about possible false alarms, possibly due to the detector sensitivity and large field of view, resulting in a negotiated change to procedures (moving the item container into the NDA room).

14. In terms of functionality, suggestions were made that the alert signal following a detection could be improved, for example, by adding an alert sound. Inspectors expressed a desire also to have open access to a log of timestamps for when alerts had been detected. A suggestion was made that portal monitor alerts should be logged in time in parallel with the CCTV system.

Handheld neutron and gamma detectors

15. Evaluators and exercise participants offered suggestions for improving the design of handheld detectors that may be used in inspections:

- As the detectors were heavy, and it was sometimes awkward to sweep along the vertical walls, particularly at the ceiling level which required taller host team members to carry out the activity. Perhaps detectors need to be placed on a rod to reach higher places, and their weight reduced, if feasible.
- The gamma detector crystal was small, which meant that sweeping the wall was slow.
- The gamma detector had an additional capability that allowed for identification of isotopics, which is a host information protection concern. In the exercise, it was handled with an administrative control (i.e., don't use that setting) and operated by host personnel, but engineering controls, or a design that excludes a sensitive capability, would be better.

Sealing

16. Inspectors applied a large number of seals during the exercise. Various suggestions were made for the available sealing kit to be improved:

- Consistency in the photographing of seals and their reflective particle matrix proved to be challenging, especially where seals were applied in locations where use of a camera was difficult. Even where camera access was not a problem, more could be done to ensure consistency with respect to the distance from which photos are taken and the angle at which they are taken. The use of a tripod, for example, could be helpful.
- Only one kind of seal (i.e., adhesive seal of one size) was available. Different seal types (e.g., loop seals, adhesive seals of various sizes) may be better suited to some situations. Some inspectors considered the use of paper/plastic seals to be too rudimentary.
- Evaluators considered that some seals applied during the exercise might have been compromised (in a minor way), either due a poor application or their use in a situation for which they are not well suited.

Local Communications

17. Exercise players commented that tools to facilitate communication between host and inspector teams, and also within teams, could be further developed. Such tools are important for communication with people working in a controlled area. Handheld radios were used by most NuDiVe teams, although inspectors were limited to use of a fixed-line telephone – held up to their ear by a host team member when working in the controlled area to prevent the inspector from touching the surface. An alternative could be to use CCTV as an intercom (cameras used in NuDiVe were not set up to record sound). This should not require inspectors to touch any communications device when working in a controlled area.

Inspector dress in controlled area

18. High-density polyethylene (Tyvek) inspection suits were used by inspectors in the controlled area to prevent swipe sampling. The impact of hot and uncomfortable suits on inspector performance and wellbeing was a subject of considerable discussion during the exercise. Various suggestions

were made, either to review the strictness of requirements for their use, and/or to develop suits with materials and design features better suited to use during inspections. Evaluators recognise that avoidance of swipe sampling will be an important requirement, especially in multi-purpose facilities. IPNDV should discuss ways to mitigate impacts on inspection effectiveness and inspector wellbeing that may result from the use of inspection suits of the kind used in NuDiVe.

Facility design

19. Although a facility where verification is conducted is not per se inspection equipment or technology, it is recognised that the facility design will be an important factor in verification. NuDiVe did not address the larger question of whether a purpose-built facility is needed, but did offer a few lessons on aspects of facility design:

- The size of the controlled area rooms may be a significant limiting factor for the pace of inspections. Requests by the inspection team to conduct some activities in parallel were not able to be accommodated.
- Entry and exit from the controlled area was also a limiting factor for the pace of inspection activities. The available facilities and space at the entry point slowed the dressing and undressing of inspectors.
- The presence of various ports in the dismantlement room (e.g., for power, water, air-conditioning) complicated sealing requirements. If a room design that minimises such ports is possible, it could aid inspection efficiency.
- The reluctance of the host team to share information with inspectors to enable them to plan their activities appeared to be a result of sensitivities about facility design. To overcome the kinds of delays experienced during NuDiVe, ways will need to be found to share enough information for effective inspection planning.

Additional suggestions

20. A number of participants identified a need for further work on measurement techniques and information barriers. For example, evaluators noted that there was a general assumption in the exercise that radiation count rates (background, warhead components) are minor and shareable. These may not be good assumptions in reality, and may lead to false positives. Information barrier techniques may be needed for the radiation detection technologies to prevent disclosure of background count rates.

21. Several participants highlighted the need for further work on authentication / certification procedures (these were not exercised).

22. Various ad hoc approaches needed to be explored by the host team for demonstrating that some items (e.g., shrouded removable tools) are non-nuclear. Further work is required on approaches to confirm that an item is non-nuclear without divulging sensitive information.

23. To attempt to detect a possible wall cavity adjacent to the dismantlement room, inspectors asked host team members to knock on walls to listen for changes in acoustics. This is a very rudimentary technique and work on additional approaches could be considered.

Evaluation results: Value of inspection approaches and exercise procedures

24. After working with the detailed inspection procedures prepared for NuDiVe, the inspection team judged that it had been able to apply adequate C&S measures to detect any diversion of fissile material from the dismantlement area. These procedures were based on the inspection approaches developed by IPNDV (see Box 1). This attests positively to the value of the IPNDV-developed concepts and of the organiser-developed NuDiVe procedures. It was evident, however, to evaluators and participants that much could be done to improve the efficiency of the procedures and how they were applied in NuDiVe. Improved efficiency should also enhance effectiveness and limit mistakes.

25. Many of the participants implementing the NuDiVe procedures said that the procedures were well written and praised their helpful detail and clarity. Suggestions were made that a flow-chart approach to their presentation could be useful also to assist with visualisation of inspection tasks.

26. The clarity of the procedures document was probably a significant factor aiding its use. Evaluators formed a view, however, that reliance on following the procedures came at a cost to independent and strategic thinking for both inspection and host team members. The evaluation team observed some in-play mistakes[6] that may have been due to a narrow focus on application of inspection procedures. Additional training in the application of exercise-specific procedures could help here (see *training*), however, the evaluators consider that this could only be one part of an answer.

27. NuDiVe inspectors planned their inspection activities on the basis of only limited information about the locations where they would conduct inspection activities. They also had little information about verification activities that had notionally taken place during earlier inspections. They worked from first principles to establish C&S in the controlled area, including by sealing off a wide range of possible diversion routes.

A systems approach

28. Evaluators felt that inspectors may be able to fulfil their task with less effort than was needed in NuDiVe if inspection tasks could be prioritised based on a holistic approach to risk. For example, the effort required for placement and checking of seals by inspectors could be reduced. IPNDV has begun a discussion on applying a "systems approach" to verification on the basis that not all verification measures would need to be applied at every step, and confidence in the overall effort is built through the combination of activities throughout an ongoing dismantlement process. In light of the NuDiVe experience, the evaluators recommend that IPNDV further discusses how a systems approach could be applied to the design of C&S systems. In this respect, the scenario and inspection activities in NuDiVe could provide the basis for a case study, with the aim of identifying efficiencies.

29. Adoption of a systems approach in inspections requires that inspectors are well briefed on the physical scenario they will face on the ground and on the history of (and future plans for) verification at the site. Such information was not available in NuDiVe before inspection activities began. While

6 For example, evaluators noted that focus on shift-change procedures sometimes distracted players from passing on necessary information to their replacements.

this offers a lesson for planning of future exercises, it also highlights the need for IPNDV to discuss the kinds of information that should be available to inspectors for their planning, including planning that may be conducted within a verification entity prior to the despatch of an inspection team, as well as the associated timeline for sharing information.

Inspection guidance documents

30. The primary written guidance for the conduct of inspection activities in NuDiVe was a set of procedures on the use of inspection equipment in the controlled area. There was also a document with "behavioural rules". Some of the behavioural rules addressed gameplay, as well as real-world safety issues for the Jülich site. They also included guidance on inspector dress and behaviour, especially in the controlled area.

31. Some confusion arose on the in-game status of the inspection procedures document – in particular, whether the procedures were fixed (e.g. treaty level) and about what scope there was to add to them or adapt them. It became clear several times that additional activities may be needed to resolve disputes or to address unexpected events. In response, the organisers clarified that some latitude to add new procedures was possible. Evaluators observed discussion in the host team on how wide such latitude should be, with some players expressing a concern that flexibility should not be excessive. It is recommended for future exercises that such guidance be clear prior to the start of the exercise.

32. The evaluators observed several examples of issues that may need to be addressed in inspection guidance. Some of these go beyond the addition of new practical procedures and point to the need for IPNDV to consider a wider set of guidance that would be appropriate for a multilateral inspection regime and which facilitates a balancing of the interests of participants in an inspection:

- The procedures did not include a mechanism to protect inspectors' working documents or tools (e.g. laptops) overnight within the inspection team's planning room, outside of the controlled area. Aside from the need for specific sealing tools, this observation highlights a need to consider the privileges and immunities that should apply for inspectors and their documents.
- The inspection team expressed concerns that it should have adequate assurance that its health and safety is being protected. For the purpose of the exercise, appropriate guidance on health and safety was provided by the organisers. The inspection team request highlights, however, that inspection guidance should clarify how inspectors can be assured that local arrangements are adequate.
- The inspection team formed a view that at least two functional layers of C&S measures would be needed for them to gain adequate confidence of non-diversion when the accountable item was present in the dismantlement room. Inspectors considered that problems with the CCTV had undermined confidence in one of these layers and wished to apply additional sealing to compensate. The host team had a different perspective on this matter. A technical standard on such issues would normally be part of higher-level inspection guidance and should help to avoid disputes on such issues.
- Although many managed access restrictions were built into the procedures, they could not address all situations (e.g. the discussion on sealing of the dismantlement room door was

conducted on the spot by team leaders). Principles on how managed access should be negotiated need to be available.

33. To facilitate a shift from the very conceptual work of IPNDV to the very practical requirements of an inspection or exercise, the evaluators propose that IPNDV considers the nature and structure of guidance that would be needed to support a multilateral inspection and that this could be made clear for future exercises. For example, the elements of a framework might include:

- probable rights and obligations under a multilateral verification agreement, for example on access and managed access, as well as on issues such as the application of inspector privileges and immunities;
- approved inspection types and objectives (and generalised equipment requirements) that would be common to all inspected parties under a multilateral agreement;
- inspection performance standards and standard techniques and procedures;
- declaration and information sharing requirements, including information needed for effective inspection planning, such as facility design information and information on past inspection activities at a site;
- site-specific requirements agreed by the verification entity and inspected state, including agreed managed access and local escort rules and health and safety requirements.

Evaluation results: Interaction between the inspection and host teams

Inspector-host team dynamics

34. All players contributed to the NuDiVe exercise in a positive and professional way. At the same time, evaluators observed examples of competitive team dynamics that could come to impede the effective conduct of an inspection. Enforced separation of teams early in the exercise may have promoted a more adversarial culture, and evaluators saw examples of improved cooperation later in the exercise. Perceptions (on both sides) of a power imbalance between the teams was also a factor.

35. Formal meetings between the teams were business-like and focused on the practical implementation of the inspection. However, the meetings were not able to enter into more substantive discussions that may have enhanced interaction and improved inspection efficiency. Initially, the inspection team's limited knowledge of the controlled area was an impediment. Subsequently, the pressure to complete all activities within the week would have constrained discussions. The inspection and host team leaders agreed to regular additional meetings to try to improve the situation.

36. During activities in the controlled area, evaluators observed some examples of a very controlling approach by host team escorts. This may have been due to a combination of strict requirements in the behavioural rules related to safety and security, along with inexperience in host team members. Host players may have been anxious to avoid any mistake that could "expose sensitive information". They were often zealous in the application of rules about the movement of inspectors and on some occasions denied apparently reasonable inspector requests. Conversely, inspectors were passive and focused mainly on completing tasks according to procedures. The evaluators observed a few exceptions to this dynamic as confidence with the situation grew. A few inspectors convinced

escorts that an alternative methodology would be more efficient and some escorts showed flexibility after observing physical discomfort of inspectors in the Tyvek suits.

37. A number of comments in post-exercise questionnaires reflected on challenges raised by a power imbalance between the teams, for example the inability of the inspection team to handle their own radiation detection or C&S equipment. Such a perception may be inevitable for inspections at high security sites, but could colour the judgements that inspectors make with respect to confidence. IPNDV may wish to consider ways in which this problem could be managed.

38. Some player comments and evaluator observations reflected on the 1:1 ratio of host escorts to inspectors used during the exercise. Some felt that additional host escort could be needed, although this would have presented challenges due to the small size of some rooms.

Dispute management

39. Differences of view between the inspection and host team were managed respectfully. Not all disputes were resolved to the satisfaction of both sides, however. In part, this was due to time limitations in the exercise. The (understandable) artificiality of an exercise may also have been a factor. With limited information available to them about the larger context of verification requirements and national concerns, both host and inspection teams may have played to be competitive rather than to resolve a real problem. The fact that the exercise was a game may have led some players to discount the consequences of an unresolved dispute.

40. Artificialities aside, the evaluation team considers that much could be done to promote a cooperative culture, with both sides working toward a common purpose. Early and regular discussions between the teams (both formal and informal) about their respective objectives would be a useful step, but is of limited value unless both sides have an adequate understanding of the physical scenario. During NuDiVe, this detail only became clearer toward the end of the exercise. Some participants suggested that a future exercise might alternate host and inspector roles to find the most cooperative outcomes.

41. Of course, a cooperative inspection culture must still be one where trust is verified. It was appropriate that both host and inspections teams were cautious of the other, although caution should not become distrust without good reason.

42. Evaluators suggest that some of the disagreements that arose during the inspection might have been more easily addressed if the inspection activity was accompanied by a structured higher-level dialogue on the plans and objectives of each side in the inspection. Some such dialogue took place, but was largely ad hoc, leading the two team leaders to propose a regular meeting schedule. This proposal probably came too late in the exercise to be fully useful, however. Additional, but flexible, guidance on the need for routine meetings and on the purpose of those meetings could be developed by IPNDV and/or future exercise organisers.

Managed access

43. Numerous constraints on inspector access were of course built into the procedures applied during NuDiVe. However, the exercise also offered some opportunity to test negotiations on access to resolve a problem. One example was created by the organisers. Within the controlled area's

dismantlement room, there was a shrouded box and a tool box, neither of which could be opened for the inspection team nor sealed. There was an interesting discussion within the host team on access options, which highlighted the importance of tools to demonstrate that an item is "not a nuclear object". The inspection team did not pursue the issue, however, and appeared satisfied by a simple gamma detection test.

44. A robust negotiation on "access" did arise late in the inspection about the possibility of applying a seal to the door of the dismantlement room containing the declared item. Inspectors proposed this task following problems with some other elements of the C&S framework (i.e., CCTV and portal monitor), but the proposal was not agreed and the treaty item was returned to its original storage location.

Evaluation results: Overall assessment of inspection activities

45. Both inspection and host teams appeared satisfied that they had been able to do their job, even if time had prevented the actual completion of all steps. A significant challenge came from the details of the building (many diversion pathways, etc.) that may not be present for other locations, especially facilities that are purpose-built, or specially modified.

46. Evaluators and exercise participants consider that the exercise demonstrated that the applicable IPNDV-developed inspection concepts and approaches are sound. The detailed inspection procedures were clear and usable, but their application proved to be slow. Refinements (including as outlined in this report) should be considered. The application of a systems approach during inspections could do much to improve efficiency.

47. Inspection equipment employed in the exercise demonstrated its value. It was clear, however that failure of equipment, or doubts about its performance, could seriously undermine confidence. Significant work needs to be done not just to develop useful technologies that can support exercises, but also to produce systems that will be functional and reliable in the context of an inspection.

48. It should be recalled that NuDiVe has (understandably) been able to test only a limited part of inspection activities around dismantlement, although many lessons could have wider value.

Evaluation results: Assessment of the exercise scenario design, venue and organisation

49. Evaluators observed that the inspection approaches in steps 8.1, 8.3 and 8.4 (see Box 1) on verification of NED dismantlement developed by IPNDV were not explicitly referenced during the NuDiVe exercise. However they provided a basis for the procedures applied in the exercise. Also, the strategies ultimately pursued by the inspection team were, in the view of the evaluators, consistent with them. In this respect, NuDiVe has been effective for testing IPNDV thinking.

50. To date, much of IPNDV's work on tools and technologies for verifying nuclear weapon dismantlement has had a conceptual focus. Implementation of verification concepts in an exercise requires a significantly greater focus on detail. The NuDiVe exercise has made a critical new contribution to moving "from paper to practice", especially by testing a multilateral methodology. It has broadly affirmed IPNDV-developed concepts, but it has also highlighted some of the considerable challenges of moving from theory to practice. In the view of the evaluators, the single

biggest lesson to be addressed is that in implementing the detail of an inspection; efficiency and effectiveness will be aided by keeping strategic inspection objectives firmly in mind.

51. The inspection scenario developed by the exercise organisers, and the facilities offered by the Jülich Research Centre, added realism to the exercise. Within the unavoidably narrow scope of an exercise at this scale, they provided an excellent foundation for work.

Lessons for future exercises: Training

52. Artificialities in an exercise such as NuDiVe should be kept in mind when assessing its results. Few participants had prior training in application of the procedures nor the technologies, and most arrived without a clear strategy in mind. This could account for some of the problems and inefficiencies observed during the exercise. Indeed, it was evident that the pace of work improved as both inspectors and hosts gained experience with the procedures. NuDiVe included a helpful training element, but this could not be compared to the deep training provided to inspectors under existing arms-control and non-proliferation agreements. In many states, personnel facilitating inspections would have significant training also.

53. To get the best out of future gameplay exercises, playing teams should be more fully trained ahead of an exercise. The evaluators recommend that IPNDV considers how it may establish a cadre of experts with training in techniques and methodologies relevant to nuclear disarmament verification. Training could be organised in the period leading up to an exercise, but might also be done routinely (perhaps annually). Such training could also help to engage additional countries in work on nuclear disarmament verification and engage new experts in IPNDV's work. It would also help to maintain expertise, so that the lessons from exercises such as NuDiVe are not lost. An early step in this direction could be for IPNDV to prepare a list of relevant competencies for which a training program could be developed.

54. In terms of technical substance, however, many NuDiVe participants commented positively with respect to the training provided to them.

Lessons for future exercises: Exercise management

55. Many NuDiVe participants commented on some confusion in gameplay at the beginning of the exercise. The combined role of blue-shirted players as organisers, trainers, and host team support was a significant factor here. A statement by the organisers clarifying roles was helpful, but the inclusion of training in gameplay was problematic. Beginning the exercise after the training period should have helped to establish clear lines of communication between the inspection and host teams from the outset of the game. It would also have been better to formally make facility support personnel part of the host team.

56. Although the "free-play" principle is important in most exercises, there is also a need for active management by a control team if things go off track. The evaluators observed the emergence of a few problems during the exercise that might have been addressed more smoothly through an early intervention. A practice in other kinds of "field exercises" is for a control team to define a series of milestones for inspection progress along with possible injects to redirect play if necessary. Injects could also be "forced" if the control team wishes to test a particular question. In this respect, it is often the case that the host team leader works as an arm of the control team.

57. In addition to the inspection procedures, the organisers issued a document with "behavioural rules". In the main, these rules addressed the conduct of gameplay as well as real-world safety issues. However, they also included guidance on inspector dress and behaviour that would have been better placed in the inspection procedures.

58. As noted earlier in this report, the guidance from which teams would work in an actual inspection would be wider than that used in NuDiVe. Both inspection and host teams often needed to create policy on certain issues as they went along. It appeared to evaluators that some host team members may have taken an overly cautious approach to inspector access because they did not know clearly what is sensitive and where they may have flexibility. Additional guidance for teams would be useful in future exercises so that each can work to a coherent strategy.

59. Evaluators noted that greater diversity among exercise players is key for better outcomes, both in terms of gender, professional expertise and countries represented.

Lessons for future exercises: Issues that could be tested in future exercises

60. The following are a number of comments and observations recorded by the evaluation team on potential areas for testing in future exercises:

a) An exercise could explore submission of declarations, inspection planning and notification, etc.
b) Exercising beyond step 8 in the 14-step process should be considered.
c) Equipment authentication/certification issues should be tested.
d) Further work on measurement techniques and information barriers could be useful.
e) Verifying design features of the dismantlement room, and sealing plans should be further explored.
f) Additional methods and tools for C&S measures should be considered.
g) Effort should be made to streamline or minimise time-consuming procedures.
h) Within the controlled area's dismantlement room, there was a shrouded box and a tool box; neither can be opened nor sealed for the inspection team. The host team discussed options to allow the inspection team to satisfy itself that no nuclear item was hidden. This did not ultimately play out, likely due to time constraints. Managed access scenarios such as this should be tested.
i) Additional approaches could be tested for transferring data from a controlled area to inspection team offices.
j) Integrated and systematic use of surveillance devices should be examined.
k) Shift-change / rotation procedures could be improved/standardised.
l) Regarding the environmental samples, strict measures such as the whole body scanner are needed to keep security.

Concluding remarks

61. The NuDiVe exercise provided an excellent opportunity to tests concepts and approaches developed by IPNDV. Although the exercise focused on specific aspects of on-site inspections for verifying nuclear weapon dismantlement, many of the lessons will have wider application in relation

to IPNDV's 14-step process. The experience offers a potentially very useful basis for some work in IPNDV's phase III.

62. On the one hand, NuDiVe demonstrated that IPNDV's work on verification requirements for Step 8 (dismantlement) is heading in the right direction. It also brought into relief the many challenges of translating IPNDV's conceptual work into a regime that is practical and usable. It has offered a first opportunity for many IPNDV partners to engage in a gameplay exercise relevant to IPNDV's work.

63. The evaluators acknowledge the very significant efforts of the organisers to prepare for NuDiVe, including to make the Jülich facility available, to and to prepare the scenario, equipment, procedures and training. IPNDV could benefit significantly if at least part of this significant investment could be reused and built on in a follow-up to NuDiVe, or other future exercises.