How might states, or the international community, go about implementing the dismantlement of nuclear weapons systems in an accurate way which would engender international confidence?

Wyn Q. Bowen[1] and Andreas Persbo[2]

February 2009

Executive summary

The paper examines the technical steps associated with the process of dismantling nuclear weapon systems in a verifiable way to generate international confidence that nuclear weapon states will fully comply with any future commitments to disarm. Part one presents the concept of a 'dismantlement flow' by examining the key elements of dismantlement that will need to be subjected to monitoring and verification if sufficient confidence is to be generated in both incremental and final disarmament outcomes. The following elements of the dismantlement flow are examined:

- monitoring options at deployment sites;
- transportation of warheads (monitoring; tagging; sealing);
- interim storage; safety/integrity checks (monitoring; authentication);
- pit and high explosive (HE) removal (safety, monitoring);
- interim storage of pit; destruction of HE (monitoring, tagging, sealing);
- removal of electronics, guidance, radar, etc (monitoring);
- non-nuclear component waste flows (monitoring);
- final pit storage (monitoring, tagging, sealing);
- pit disassembly and conversion.

Part two then presents the concept of a 'dismantlement doctrine' comprising a

[1] Centre for Science and Security Studies, King's College, Strand, London WC2R 2LS.
E-mail. wyn.bowen@kcl.ac.uk Tel. 44(0)20 7848 2942
[2] Verification Research, Training and Information Centre (VERTIC).

fundamental set of principles to inform and guide the dismantlement process. While the principles are fundamental to any dismantlement process in the context of negotiated nuclear disarmament, the specific context and circumstances of each case will probably necessitate a level of judgment in their application. The paper presents the following four core principles:

- 'human factors': the building of personal relationships at the operational level to engender trust and confidence;
- technology: the relevance of both high and low technology approaches to monitoring and verification;
- the legal instrument: the legal basis of verification;
- 'conditions for configuration': organisational and political representation issues at the operational level.

PART I: DISMANTLEMENT FLOW

The dismantlement of a nuclear warhead is a complicated procedure; it is not as simple as just rolling the weapon into a clean laboratory and starting to pull it apart. It is more similar to a very hazardous industrial activity involving many steps, each of which poses several practical challenges. These challenges can be divided into three distinct categories which are relevant to various degrees to all steps in the dismantlement flow: health and safety, physical security and non-proliferation.

First, the dismantling state is required to put in place and maintain very strict health and safety requirements. There are many risks involved with dismantling a nuclear weapon. For instance, mishandling the fissionable material by dropping the bare or reflected metal assembly, can lead to a criticality accident likely to expose dismantlement workers to fatal doses of radiation.[3] The high explosives used in nuclear weapons are exceptionally stable but also very powerful.[4] They need to be handled with great care and in accordance with the strict regulations often in force in respect to explosives so as to avoid accidental detonation.

Second, the dismantling state is required to observe a strict physical protection regime. Even a remote likelihood that a nuclear warhead or associated materials could fall into the wrong hands warrants heavy security. This means that inspectors may have to be kept in the dark about certain aspects of the dismantlement process. For instance, transportation schedules may not be divulged and this might have an impact

---

[3] A criticality accident occurs when a nuclear chain reaction accidentally occurs in fissile material, such as enriched uranium or plutonium. This releases neutron radiation which is highly dangerous to surrounding personnel and causes induced radioactivity in the surroundings. The criticality accident is associated with a blue flash of light and a heat wave.

[4] Cyclotetramethylene Tetranitramine ('HMX') is used in many nuclear weapons. This explosive is not known to react with any chemicals, it remains stable when heated, but it can explode under very heavy shock or friction. It is a very powerful explosive, with a detonation velocity of about 9,100 meters per second. Trinitrotoluene ('TNT') has a detonation velocity of about 6,900 meters per second.

on ‘chain of custody’ issues. For example, if inspectors are not given access to all areas at a particular site and without explanation, this might give rise to legitimate suspicions.

Third, the dismantling state needs to observe its non-proliferation obligations. This is sometimes viewed as the most difficult challenge in the verification of nuclear arms control. Information on warhead design should not leak to any inspectors from non-nuclear weapon states. If this did happen, then the nuclear weapon state would be in breach of its commitments under article I of the 1968 Nuclear Non-Proliferation Treaty (NPT). What is rather less recognized is that the non-nuclear weapon state *would also be in breach* of its commitments under article II of the treaty. Therefore, the obligation not to proliferate nuclear-weapons relevant knowledge lies on both the inspected and the inspector states.

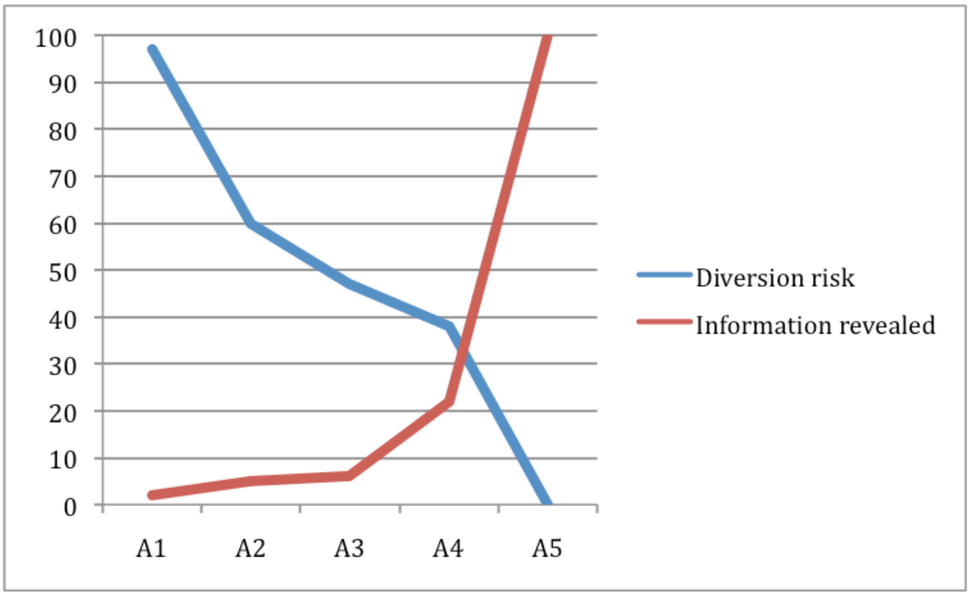
Envisioning the dismantlement flow

The easiest way to describe the dismantlement process is to envision a flow of material. It starts with the assembled weapon moving into the facility. As the weapon moves through the facility, it gradually loses its internal components, creating new flows of material. First, the ‘physics package’ (the fissionable core and the high explosives) is removed from the weapon and diverted for separate processing. After that, the empty bomb shell gets stripped of its electronics and aerodynamic equipment, and this creates streams of material of various classification levels. Each weapon can contain several thousand individual parts—not all can be safely disposed of in a similar manner and some parts are more proliferation sensitive than others.

One could assign values to both the level of security concern and the proliferation risk at each stage of the dismantlement process, should non-security cleared personnel, such as inspectors, be present. The nuclear weapon state will have legitimate security concerns at the front-end of the dismantlement flow where weapons are deployed. Non-cleared personnel could get access to weapons operations or doctrine, they would be able to observe physical security, and have access to a wealth of other information that has direct relevance to military operations. On the other hand, there are few proliferation risks involved: simply observing a nuclear weapon casing will not give away much sensitive design information. The proliferation risk increases the more disassembled the device is, whereas the security risk decreases as the weapon gradually becomes unusable.

Inspector access must be carefully considered when designing the verification system. As indicated above, the general rule is that the more access the inspector gets, the more classified information is exposed. A 1969 study by the US Arms Control and Disarmament Agency concluded that relatively few classified items are exposed at low access levels (managed visual observation) whereas a large number of items are exposed at full access levels (no restrictions on observations or measurements). The introduction of photography and neutron counting technology dramatically increased the numbers of exposed items.

The exercise comprised several hundred real warheads that were due for decommissioning and a large number of fake weapons. Inspectors were required to call a fake weapon only when they could cite grounds for doing so. No attempt was made to conceal warhead components at various access levels. Inspection teams were given the right to visual observation only (level A1) through complete access to the warhead (level A5). At level A4, a number of sophisticated verification techniques were applied: the teams were allowed to use unshielded gamma spectrometers and were also permitted to x-ray the weapon. The study demonstrated that it was very difficult to avoid having classified information being exposed to the inspector. It also showed that the ability to correctly call a fake weapon when inspectors only had the right to visual inspections was unacceptably low.[5]



(Source: Cloud Gap, 1969)

The key, consequently, is to find a solution that minimizes the proliferation and security risks while at the same time maximizes detectability. In order to do this, one has to carefully examine the entire dismantlement flow in order to assess where maximum verification benefit can be achieved at a minimum of proliferation and security costs.

This paper will now briefly discuss verification options at various sites that the warhead passes through as it is being dismantled.

Deployment sites

Nuclear warheads can be deployed on a variety of delivery platforms. They can be delivered in a gravity bomb or on missiles. The missiles could in turn be deployed in silos or submarines. The gravity bombs could be stored in close proximity to the aircraft or in remote storage sites. While the issue of where and how nuclear weapons are deployed or stored is extremely sensitive, there are monitoring techniques that could be used at this stage. Declared deployment sites could have portal and perimeter monitoring arrangements in place. The site operator could declare when a nuclear warhead is being transferred in or out of the site, and inspectors would be allowed to

---

[5] During Operation Cloud Gap, inspectors were able to spot and call a fake weapon at visual inspection level access at 53 per cent of the time (which is slightly better than a coin-toss). See: Final Report, Volume I, Field Test FT-34, *Demonstrated Destruction of Nuclear Warheads*, January 1969, p.117.

verify the transfer at an agreed portal. Such arrangements were in place under the INF treaty, to verify the non-production of certain types of ballistic missiles.

Various technologies could also be deployed to monitor the store itself. For instance, nuclear warheads could be electronically tagged and put under CCTV surveillance. There have also been suggestions about using scene recognition software to enable the instantaneous detection of any unauthorized movement.[6]

Despite the presence of applicable techniques, monitoring at this stage of the warhead's life cycle seems unlikely, primarily because of security concerns.

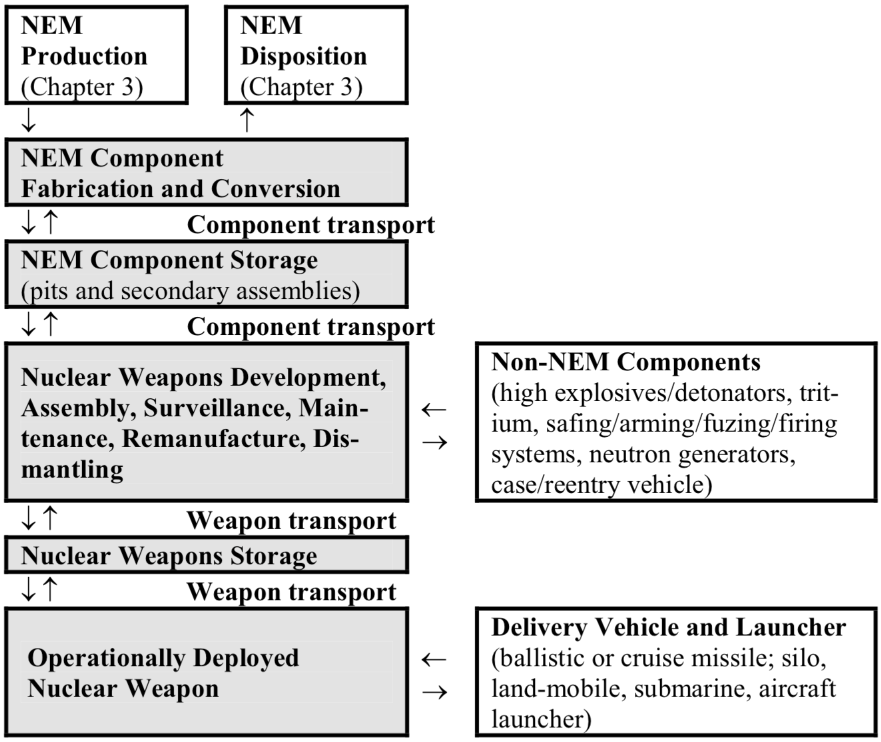


FIGURE 2-1 Life cycle of a nuclear weapon.

(Source: Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities, Committee on International Security and Arms Control, National Research Council, p. 46)

Warhead transportation

Instead of monitoring the weapon at the deployment site, inspectors could begin their activities once the weapon leaves the facility for the dismantlement site. Again, there will be many safety and security problems to overcome if inspectors are to have access to this part of the life cycle. Nuclear weapons are transported under strict security arrangements and having inspectors involved may pose a security risk, especially if transports require pre-notification or an inspector escort. However, monitoring at this stage is relatively straightforward. The weapon is first authenticated through some agreed method. The US–Russia–IAEA trilateral initiative looked into a so-called 'information barrier' concept, where a filter would compare the weapon's

---

[6] A Proposed Approach for Monitoring Nuclear Warhead Dismantlement.

signature by comparing it to a template or by looking for certain attributes.[7] In 1997, this technique went through a field trial at the storage in Mayak, Russia.[8] A similar technology is being developed through the so-called UK–Norway Process on verified dismantlement of nuclear warheads.

The weapon would thereafter need to be placed in a closed container with a tamper-indicating seal. Ideally, the container should also be tagged, so that it can be identified at a later date. However, unless there are inspectors present with the transport, tagging and sealing will provide little assurance against the weapon being swapped for a dummy whilst it is being transported.[9]

This means that authentication at the deployment site is unnecessary unless inspectors can visually confirm the integrity of the seal at certain intervals throughout the transport. To avoid accusations of tampering, the objective of certifying the weapon can instead be completed at an interim storage facility at a later date.

Interim storage

Before any weapon can be maintained or dismantled it is rolled into a receipt area at the nuclear weapons laboratory. A number of checks are carried out here to ascertain how safe the weapon is to handle. Is it emitting anything? What is the state of the high explosives? Unless it is damaged in some way, the weapon is still intact as this stage. As such, there is relatively little proliferation sensitive information that can make its way to inspectors. Usually, the weapon is removed from its transportation container. Once it has been checked, the warhead is transferred to another type of container with different characteristics. Each movement of the weapon, no matter how small, will have to be justified and logged. It is here where authentication is most useful.

Inspectors will know that the weapon is not scheduled to leave the site intact, and if they have some knowledge of how site operations are conducted, they will be able to gain some confidence that the weapon is, indeed, undergoing dismantlement. Authentication may be carried out through the employment of information barrier technology (described in more detail in Part II) in combination with visual inspection. Once the weapon is certified as real, the container may be sealed up and tagged. Inspectors could thereafter be present each time the container is moved, so that the integrity of the container is checked.

If the dismantlement facility is specifically designed for the verification process, it is possible to deploy portal and perimeter monitoring techniques. This is in many ways preferable to having dismantlement done in existing nuclear weapons laboratories. In a dedicated facility, inspectors could do a design inspection of the plant to ensure that there are no warheads or other components inside (this involves checking the building against the floor plan to make sure that there are no hidden trapdoors, concealed

---

[7] See, for instance: Rena Whiteson, Duncan W. MacArthur, and Robert P. Landry, *Functional Specifications for a Prototype Inspection System and Information Barrier*, Los Alamos National Laboratory document LA-UR-99-1174, March 1999.

[8] Richard L. Garwin, *Technologies and Procedures to Verify Warhead Status and Dismantlement*, SIPRI Workshop, Paris, 02/08-09/2001, http://www.fas.org/rlg/010208-sipri.htm.

[9] Roger G. Johnson, 'Tamper Detection for Safeguards and Treaty Monitoring: Fantasies, Realities and Potential', *Non-Proliferation Review*, Volume 8, http://cns.miis.edu/pubs/npr/vol08/81/81john.pdf

spaces, extra piping, or other undeclared construction). This would help towards ensuring that no items can be swapped or spoofed during dismantlement operations conducted inside 'black boxes'. Vehicles and personnel entering the dismantlement facility would be easier to be subjected to search by the inspectors. Other portal measurement techniques could also help to ensure that no undeclared warheads enter or leave the facility. However, a dedicated dismantlement facility may cost several hundred million dollars and would require separate environmental, safety, and health assessments, a separate security evaluation, and an operational readiness review.[10]

Pit and high explosive (HE) removal

The most important aspect of dismantlement occurs when the nuclear core (also known as 'the pit') is removed from the weapon along with surrounding high explosives (the assembly of fissile and fusion fuels plus high explosives is sometimes referred to as the 'physics package'). Under all present proposals, inspectors are not allowed access to observe the actual removal of the physics package. Inspectors able to observe how the device is actually configured may eventually deduce how the high explosive is supposed to interact with the heavy metal during detonation. Sensitive electronic components, wiring and triggers will be completely exposed. Therefore, it is widely assumed that dismantlement will be carried out inside a 'black box' (a restricted area'). Inspectors will know what enters the box, the idea being that they may be able to observe what comes out on the other side, without viewing the actual procedure.

The pit is removed and placed in a container.[11] This container cannot be assayed or weighed since that would reveal sensitive information. It is possible, however, to verify through the use of information barrier technology that a closed container contains more than an agreed amount of plutonium, and that it is of a certain grade. The container can thereafter be sealed and tagged and shipped off to a pit storage facility (see below). If the dismantlement facility is dedicated, inspectors will be certain that if there is any amount of undeclared plutonium involved, it will be contained within the facility perimeter. If dismantlement operations are conducted in an existing plant, there may be a degree of uncertainty involved, depending on how entrances and exits are monitored.

Non-nuclear component waste flows

Compared to the pit, monitoring non-nuclear component waste flows are of secondary importance. These items can be easily acquired anew by the nuclear weapon state if it decides to reassemble a weapon. However, there may be some benefit in allowing inspectors to view, for instance, the burning of high explosives, and to look at the flow of certain, less classified, weapons components (perhaps the bomb casing as well as certain electronic parts). While these flows are of marginal relevance for disarmament, transparency is likely to make inspectors more confident that they are observing a *bona fide* dismantlement process. If proper safety precautions are taken, inspectors could, without any great concerns, be invited to observe the burning of

---

[10] 'An Analysis of Potential Measures for Monitoring U.S. Nuclear Warhead Dismantlement', Volume 1: Unclassified Executive Summary of the Wilson Report, SNL, December 1993.

[11] In the United States, the container is designated AL-R8. It resembles a 130 liter steel drum filled with a fire-resistant material called Celotex.

high explosives. Again, while this has limited relevance for accountancy, it is symbolically significant, and will help increase confidence in the process as a whole.

Pit storage

The storage of the pit is by no means a straightforward procedure. The plutonium contained in the pit may generate as much as 18 watts in heat load. This means that the container may be heated up to about 50 degrees Celsius. Some pits stored in the United States' Pantex facility have been known to reach 150 degrees due to compact storage conditions. This, obviously, gives rise to risky working conditions.

Actual monitoring of the storage site is relatively simple, however. It is likely to involve sealing, tagging, perimeter monitoring and stringent accountancy of items received and shipped. A relatively high degree of certainty that no pits are shipped off to an assembly plant can be achieved if the storage site is built for purpose.

The United States and Russia worked throughout the 1990s on storage monitoring technologies that included a remote monitoring sensor network and near real time exchanges of sensor information over the Internet.[12] While work has progressed slowly throughout the 2000s, many of these proposals can be dusted off for future use.

Pit disassembly and conversion

The final step in the dismantlement process is pit disassembly and conversion of the plutonium into non-classified forms. This process involves some generic steps. First the incoming pit must be weighed and assayed to verify that the full amount of plutonium was shipped in from the storage site. The pit is then cut in half and the plutonium converted through various industrial processes. This is the most sensitive step of the conversion process, since the plutonium weight and isotopic composition is highly classified. Usually, the plant recasts the metal or mixes oxides with other plutonium oxide powders.

At the front end of the process, material accountancy could be conducted by simply counting the incoming pits. Inspectors would also weigh the amount of incoming non-classified material that the pits will be blended with.

Inspections or measurements are not likely to be allowed in the beginning of the processing campaign, but it is possible to allow visual inspection and perhaps even measurements when the material has been converted to a non-classified form. The problem is that inspectors may still be able to deduce the average weight of the pits by subtracting the amount of non-classified material from the total output and then simply divide the product with the number of incoming pits.[13] There is no simple solution, and more research must be conducted into how adequate verification can be executed at this final step of the warhead's life cycle.

---

[12] See, for instance: C.D. Croessman, C.A. Nielsen, J.C. Bartberger, J.D. Gruda, *SNL/VNIIEF Storage Monitoring Collaboration*, Sandia National Laboratories, Document SAND99-1766C.
[13] See, for instance: J. W. Toevs, *Surplus Weapons Plutonium: Technologies for Pit Dissassembly/Conversion and MOX fuel fabrication*, Sandia National Laboratories, Document LA-UR-97-4113.

Part I Conclusion

It is possible to conduct verification activities at almost all steps in the dismantlement process. The main difficulties lie with warhead authentication and material accountancy of classified plutonium pits. There is likely to be a relatively large margin of error in any accountancy, and that verification deficit would probably need to be filled by other means, such as inspector access to the process itself, including some access to relevant personnel and documentation. This leads to the question, already posed in 1967 by Allan Labowitz, the Special Assistant for Disarmament in charge of Operation Cloud Gap: is it relevant whether 'real weapons are in fact destroyed provided that the agreed amounts of fissionable materials are transferred to peaceful uses'?[14]

Since the critical part of the nuclear weapon is the fissionable material, it is difficult to argue that thorough material accountancy at the back end of the dismantlement flow would be inadequate for a nuclear disarmament instrument. However, as will be argued below, inspector involvement in broader aspects of nuclear dismantlement operations will, to some degree, help to build confidence in the overall process. From a psychological perspective, the regime is likely to be perceived as slightly more robust and trustworthy if inspectors are involved at more stages. However, whether or not the reward warrants the risks is a question very much up for debate.

PART II: DISMANTLEMENT DOCTRINE

Given the complexities associated with verifying the dismantlement process, it is important for any verification process to be informed by an underlying set of principles; a 'dismantlement doctrine' if you will. The basis of such a doctrine could include several principles, four of which might be:

- human factors (the building of personal relationships at the operational level to engender trust and confidence);
- technology (the relevance of both high and low technology approaches to monitoring and verification);
- legal instrument (the legal basis of verification);
- conditions for configuration (organisational and political representation issues at the operational level).

While such principles are likely to be central to any verification of dismantlement in the context of negotiated nuclear disarmament, each will necessitate a level of judgment in application because of the different contexts, and the specific circumstances therein, that are likely to be encountered.

Human factors

Turning first to 'human factors' where it is evident that building personal relationships at the operational level amongst the personnel involved in warhead

---

[14] US Atomic Energy Commission Memo entitled, 'Project Cloud Gap and CG-34, Demonstrated Destruction of Nuclear Weapons', 21 November 1967.

dismantlement and verification will be essential to engendering the mutual trust required for developing international confidence in the process. At one level this will involve the building of personal relationships between the inspected and inspecting parties. As Persbo and Bjorningstad note, 'interaction between the inspecting and the inspected party is likely to induce trust and cooperation, enabling more credible and efficient verification in the long run'.[15] Of course, this is likely to be a greater challenge in situations where there is, or has recently been, a significant level of hostility between countries represented on the inspection side and the country being inspected. The significance of human factors also encompasses personal relationships within the body of inspectors charged with verifying dismantlement. The inspecting personnel are likely to be drawn from several governments, at least one international organisation and possibly NGOs. An examination of the UK–Norway project is relevant in both respects.

Considerable time was spent at the beginning of the UK–Norway project on getting all sides to feel comfortable about sharing information and ideas. For the staff of the Atomic Weapons Establishment (AWE), interaction with a non-nuclear weapon state government and a non-governmental organization proved to be something of a 'culture shock'. Accustomed to working behind a veil of secrecy, the increased exposure forced the AWE personnel to revise and question several of their own assumptions on the verification of nuclear disarmament.

The open exchange of ideas that has subsequently developed has resulted in a close working relationship that quickly focussed on very simple solutions to very complex problems. The UK participants were surprised to learn that, for the Norwegian researchers, a much lower level of detectability and assurance in the verification regime was required than previously assumed. After a while, the personal relationships within the UK–Norway project developed into an *esprit de corps* going beyond national policies and priorities. A similar phenomenon occurred within the trilateral project (comprising Russia, the US and the IAEA).[16] This raises hopes that even defunct projects can be resurrected at comparably short notice.

Another example illustrative of the importance of human factors at the operational level is the work of the UN Special Commission (UNSCOM) in Iraq during the 1990s.[17] The UNSCOM experience highlights the importance of developing close working relationships amongst inspectors which, on the whole, proved to be important for engendering mutual confidence within the teams charged with monitoring and verification. The inspectors were, of course, drawn from multiple countries, albeit with UN hats on. They were also drawn from a diverse array of technical and professional backgrounds. So, not only did team members have to contend with the challenge of working with nationals from an array of countries, they also had to work across sub-disciplines, or they at least had to understand how the other sub-disciplines fitted in with their own and into the wider scheme of things. All

---

[15] Andreas Persbo and Marius Bjorningstad, Verifying Nuclear Disarmament: The Inspector's Agenda, Arms Control Today, May 2008, http://www.armscontrol.org/act/2008_05/PersboShea

[16] Personal communication with Tom Shea (former member of the Trilateral Initiative).

[17] This example is not relevant in the context of personal relations between the inspected and inspecting parties, although relationships at the individual level between UN inspectors and some of their counter-parts working for the Iraqi mirror organisation, the Iraqi National Monitoring Directorate, were relatively cordial and professional while not totally cooperative.

of this took place, of course, in a relatively unique and sometimes stressful verification environment.

The process of relationship building was assisted by the fact that numerous inspectors visited Iraq on more than one occasion and many did so regularly and over a prolonged period. For example, most verification missions in Iraq involved core groups of people drawn from the UN itself and seconded through national governments from industry, NGOs, etc, with the remainder brought on board on a less regular and sometimes one-off basis, depending in part on specific mission objectives. Members of the core group knew each other, had experience of working on the ground in Iraq, and had generally worked together in-country before. The key point is that having core groups enabled the most positive of personal relationships to develop amongst many of the inspectors, which undoubtedly strengthened their cohesion and effectiveness as monitors and verifiers.

Building such coherency within multi-national and multi-disciplinary teams, drawn from an array of countries and organisations, will be an essential part of optimising the verification process, as well as subsequent long-term monitoring once dismantlement has been completed. Moreover, it demonstrates the importance of identifying inspectors from all potential participant countries, international organisations and NGOs at the earliest possible stage so that they can begin training together on a regularised basis with the aim of maximising organisational cohesion and effectiveness.

The legal basis

The process of verifying nuclear weapons dismantlement is going to require an underlying international legal instrument or set of instruments. The following types of issues, among others, will need to be addressed at the legal level:

- the content of the declarations to be submitted by inspected parties;
- the role of inspections and remote monitoring including the procedures, specific measurement technologies (e.g. information barriers) and approaches to be applied at different stages of the dismantlement flow;
- the scope (breadth and depth) of inspections (sites, objects, documents, people);
- a mandate for a new or existing international institution to participate in the verification process;
- procedures for dispute resolution between inspected and inspecting parties;
- the participation of personnel from non-nuclear weapon states and NGOs;
- the commitment of non-NPT nuclear capable states to not proliferate nuclear weapons-relevant knowledge.

Some of these issues are likely to be more sensitive and controversial than others and many will be influenced by developments in other areas such as the development of information barrier technologies and practices. Moreover, the decision to involve the IAEA, or to create a new and specifically designed international organisation for the process, is a highly political issue and will obviously be determined at the inter-state level.

On the question of non-nuclear weapon state participation, some key questions related to dismantling nuclear weapons and the provisions of Article I under the NPT, which prohibits nuclear weapon states from transferring nuclear weapons technology to non-nuclear states, include: 'Is a nuclear-weapon state assisting another state if it unintentionally leaks weapons-relevant information, or does the assistance have to be intentional?' 'Would information on non-nuclear components constitute a breach?' Moreover, 'Under the strictest of interpretations, the risks of involving international inspectors would probably be too great. With some legal flexibility, non-nuclear-weapon state inspections could be permitted if conducted with the utmost care.'[18] Indeed, as noted shortly, it will be unavoidable for some non-nuclear weapon states to play a role in the verification process if sufficient confidence is to be generated in the implementation of agreements related to a region or world free of nuclear weapons. Successful verification will also necessitate the interaction of some states that have traditionally had the most bitter and confrontational of relationships.

Finally, while the *de jure* nuclear weapon states and non-nuclear weapon state parties to the NPT have committed themselves to not transferring nuclear weapons-relevant knowledge, the non-NPT nuclear weapon states have not done so in such a legally binding way. A legal commitment will therefore have to be made by the *de facto* weapon states which mirrors that for the *de jure* weapon states under Article I of the NPT.

Conditions for configuration

At the operational level there are conditions that will need to be met if the configuration of the verification process is to be optimised for building trust between participants. The question of the overarching political–strategic 'enabling conditions' necessary for initiating a disarmament effort in the first place is beyond the scope of this paper. However, of direct relevance to building confidence in the dismantlement process itself will be political representation issues at the operational level. These issues focus primarily on the countries (including constituent domestic actors with legitimate stakes in the process), international organisations and NGOs that will need to play a role in verifying dismantlement in any particular context. Getting this configuration right will be essential to generating sufficient breadth and depth of confidence in both incremental and final disarmament outcomes. Numerous questions spring to mind in this respect:

- How will all those countries with a perceived stake in a particular disarmament process (e.g. focusing on the Middle East), both nuclear and non-nuclear weapon states, be engaged in an organisational sense to generate the levels of confidence in the monitoring and verification process required for short- and longer term political sustainability? Do all these countries need to be directly involved?
- If regional approaches are adopted as part of the process of moving towards a nuclear weapon free world, how will these fit into the broader scheme of things in an organisational sense?

[18] Andreas Persbo and Marius Bjorningstad, 'Verifying Nuclear Disarmament: The Inspector's Agenda', *Arms Control Today*, May 2008, http://www.armscontrol.org/act/2008_05/PersboShea

- Given that, in some circumstances, operational configurations will need to bring together formerly bitter opponents, many of which will not be nuclear weapon states, how will political sensitivities be overcome and NPT requirements be met in establishing a credible organisational framework for verifying dismantlement?
- Is there a requirement for a new, specially designed and configured organisation, or set of related and regionally focused organisations, to provide a focal point for verification activities?
- Should NGOs play a role and, if so, how can suitable NGOs, with the requisite expertise to play a credible role in the process, be identified?

As a partial illustration of these questions it is useful to briefly examine the case of the Middle East. The Middle East is probably the most extreme example to consider because the region, more than any other, illustrates the complexities and sensitivities associated with formulating operational configurations for dismantlement. The region is characterised by enduring conflicts and animosities at the Arab–Israeli and intra-Arab levels and within the context of Iran's post-1979 relations with its Arab neighbours, on one hand, and Israel on the other. The role of external powers has also been an enduring security dynamic, with the United States playing the key role in this respect since the 1980s most recently with the invasion of Iraq in 2003.

Israel, of course, is the only *de facto* nuclear weapon power in the Middle East, and the political-strategic conditions in the region do not currently appear conducive to Israel taking a decision to dismantle its nuclear weapons capability any time soon. Down the line, of course, Israel may not be the sole nuclear weapon power in the region—with Iran currently causing the greatest concern on this front—and this would add further layers of complexity in terms of configuring a regional dismantlement process. Nevertheless, it is informative to speculate about those governments that would need to be represented at the operational level if Israel opted to dismantle its nuclear weapons in a way that generated and maintained the regional confidence needed to ensure the long-term durability of a nuclear disarmament agreement. For example, it would be essential to involve countries—which are all currently non-nuclear weapons states—that are neighbours of Israel and/or have been in direct or indirect conflict with that country at some point over the past 40 years or so. The list of countries is relatively lengthy and would probably need to comprise Egypt, Jordan, Syria, Iraq, Iran, Saudi Arabia, Lebanon and potentially Libya. The national threat perceptions and strategic postures of these countries have been influenced by assessments of Israel's military intentions and capabilities at both the conventional and nuclear levels. The representation of some, or all, of these countries in the verification process would appear crucial to generating confidence on the part of former adversaries and antagonists that Israel had truly complied with any commitment made to disarm. Such representation would also be important if the link between chemical and nuclear disarmament, which countries like Egypt and Syria have traditionally made, is to be cut. On this front it could be expected that Israel would insist on reciprocal representation in a regional verification process in the chemical area.

It does, of course, take a major stretch of the imagination to envision a verification mechanism comprising representatives from these countries working in Israel to monitor the dismantlement of its nuclear weapons in conjunction with a relevant international organisation, NGOs and other nuclear weapon states. The level of mistrust likely to exist between inspected and inspecting parties would be a key issue running through the entire verification process, with a direct impact on political representation at the operational level. It will also influence the level of intrusiveness required of verification processes and technologies. However, if a comprehensive peace is eventually negotiated in the Middle East, then the prospects for such a configuration would obviously improve. Indeed, the 'enabling conditions' for negotiating a comprehensive peace in the region would obviously have to address, or at the very least lay the foundations for addressing, the nuclear question and associated chemical and biological weapons issues too.

Given the sheer scale of the challenges and the political significance of moving towards a nuclear weapon free world, and while the IAEA has played an important role in verifiably dismantling nuclear weapons programmes in the past, the high levels of confidence required of the verification process, and on the part of multiple parties, may necessitate the establishment of a new multilateral verification organisation. Such an institution could be specifically established and configured for verifying warhead dismantlement processes and the subsequent monitoring of former and potential nuclear weaponisation related facilities. Obviously, an organisation of this type would have to work in close collaboration with the IAEA because of its nuclear safeguards mandate. However, establishing a new body with a singular focus, without the distraction of promoting and policing civil nuclear activities as the nuclear power renaissance promises to take hold, may be the most attractive option for the *de jure* and *de facto* nuclear weapon states. A new organisation could be set up from first principles and be largely unaffected by legacy issues, including for example the long thorny question of the IAEA role in dealing with weaponisation related questions. The bulk of personnel could be seconded from nuclear weapon states but with representation from key non-nuclear weapon states. Non-nuclear weapon state participation could be determined by one of two criteria: by potential contributions at a tangible level, for example in terms of relevant technical expertise; and more intangibly in terms of political representation as part of generating confidence in specific dismantlement processes. Setting up a new body could offer the best approach for protecting sensitive nuclear weapon design information and minimising the risks of proliferation. It could also be the best approach to developing confidence amongst relevant parties regarding the utility and reliability of new verification technologies including information barriers. Of course, a new organisation would also have to pay major attention to external and internal information security just in case some inspectors, from nuclear or non-nuclear weapon states, are engaged in espionage whether targeted against a particular country or more generally focused on gathering proliferation sensitive data.[19]

Technology

It is apparent that low- and high-technology approaches will play a pivotal role in the verification process, whether technological fixes are currently available or in development. At one end of the spectrum, as already noted, there will be a requirement for tags with unique identifiers to be placed on objects subject to verification, as well as tamper indicating seals to detect unauthorised movement of, or

[19] Andreas Persbo, May 2008.

access to, them by the inspected party.[20] One problem with tags and seals is that, while they are designed to be tamper proof, they cannot be relied upon to be 100% effective in the face of a state party determined to deceive a verification mechanism. Movement/intrusion sensors will probably be placed on the perimeter of relevant facilities to discourage and detect unauthorised entry and exit. This can be combined with other basic verification technologies including video surveillance (CCTV) and time lapse photography for monitoring the perimeters or the interiors of facilities.[21] Environmental monitoring could also play a role in terms of 'wide area remote sensing; ground based monitoring of liquid and gaseous effluent emissions; portable on-site inspection equipment; and laboratory-based sample analysis techniques'.[22] All of these technically-based approaches could be complemented by 'occasional inspections of the interior of the facility (during periods when no nuclear weapons were being dismantled) to confirm that there was no buildup of nuclear weapons or materials within the facility'.[23]

Part one touched upon the issue of warhead authentication and the concept of information barriers. In this respect, radiation measurement will play an all important role where radiation detection can be 'passive'—where systems are designed to detect emissions—or 'active'—where the object in question is 'irradiated by a source of energy like neutrons, a laser or sound wave'.[24] All types of warheads containing fissile materials will possess a unique 'signature', or 'finger-print', based on their emission of 'a characteristic radiation, either spontaneously or induced by an external source'. The signature can be measured using a radiation detector whether or not the warhead is located within a sealed container (the 'template' approach). Moreover, the signature can be used to evaluate the nuclear subcomponents once the warhead has been disassembled, which will have taken place behind closed doors.[25]

Using radiation detectors to measure the unique radiation signatures associated with particular nuclear weapon types should generate confidence that the specific warheads in question have been dismantled rather than dummy or hoax warheads. By the late 1990s the United States had tested 'radiation signature technologies' demonstrating 'an effective discrimination by type of warhead and a correlation of type of warhead with dismantled nuclear components'.[26] However, an important issue with the template approach is 'how to confirm that the objects measured to get the templates are actually nuclear weapons'?[27] In addition to taking measurements of the emission

---

[20] Kai-Henrik Barth, 'Nuclear Weapons: Monitoring Warhead Dismantlement', CRS Report for Congress, 4 November 1999, p.5.
[21] See: Kai-Henrik Barth, 4 November 1999, p.4; *The United Kingdom's Defence Nuclear Weapons Programme*, A Summary Report by the Ministry Of Defence on the Study Conducted by the Atomic Weapons Establishment Aldermaston into The United Kingdom's Capabilities to Verify the Reduction and Elimination of Nuclear Weapons, UK Ministry of Defence, 2000, http://www.mod.uk/NR/rdonlyres/3B3D7417-EAE1-487F-A0BB-891E841FA973/0/nuclearweaponsverification.pdf
[22] Garry J. George and Martin D. Ley, 'Nuclear Warhead Arms Control Research art AEW', *VERTIC Yearbook 2001*, pp.200-201.
[23] Matthew Bunn, 'Transparent and Irreversible Dismantlement of Nuclear Weapons', in *Reykjavik Revisited: Steps Toward a World Free of Nuclear Weapons*, pages 205-227 (Stanford, CA: Hoover Institution Press, 2008), pp. 217-221.
[24] Garry J. George and Martin D. Ley, p.205.
[25] See: Kai-Henrik Barth, p.4.
[26] Ibid, pp.4-5
[27] Matthew Bunn, pp. 217-221.

rate of gamma rays and neutrons at particular locations, warhead authentication could also incorporate measurement of ‘size, weight, and heat output’: as Fetter notes further, ‘A signature with such detail would be extremely difficult to counterfeit, but it might raise concerns that sensitive design information was being revealed’.[28]

An ‘attribute’ approach would be based on measuring the special characteristics of nuclear warheads. These characteristics include the size of the object being examined, the mass of weapons usable material, its metallic form, and the presence of high explosives. However, this approach necessitates broader measurement parameters to provide for all types of weapons and will increase the potential for decoys to get through under the wire.[29] The template approach is more accurate, then, but carries with it greater concerns about revealing sensitive design information, while the attribute approach is less accurate but does not carry as high level of risk related to the leakage of national security information. As the UK Atomic Weapons Establishment notes, ‘Any measurement will provide some degree of design information…’[30]

As noted earlier the technical and procedural fix here is the ‘information barrier’ which ‘consists of procedures and technology that prevent the release of sensitive information during a joint inspection of a sensitive nuclear item, and provides confidence that the measurement system into which it has been integrated functions exactly as designed and constructed’.[31] In short, an information barrier ensures that inspectors do not get to view the detailed results from the measurement device just a positive or negative indication that the device being examined corresponds to a template or a set of attributes.[32]

The key technical question, then, is how to generate confidence on the part of inspectors that the measuring equipment is operating with the correct criteria for the warheads in question? Moreover, the inspected party will want to ensure the measuring equipment does not give away design information. As Bunn notes, equipment based around the template or attribute approach can be developed with ‘simple hardware and software, where every line of the code can be inspected; arrangements can also be made in which the systems are built by the inspecting side, which would build extra copies of the systems so that the inspected side could choose which one would be used and take another apart to confirm that it was not designed to collect information beyond that agreed to’.[33] Importantly, the UK–Norway project is conducting research on ‘an information barrier system and procedures’ with the aim of developing something ‘that will be credible and mutually acceptable to all parties under future disarmament treaties’.[34]

---

[28] Steve Fetter, ‘Verifying Nuclear Disarmament’, Pugwash Paper. 3/12/98 DRAFT, p.8.
[29] Matthew Bunn, pp. 217-221.
[30] The United Kingdom's Defence Nuclear Weapons Programme.
[31] J.L. Fuller and J.K. Wolford, ‘Information Barriers’, IAEA-SM-367/17/01, p.1, http://www-pub.iaea.org/MTCD/publications/PDF/SS-2001/Start.pdf
[32] Steve Fetter, p.8.
[33] Matthew Bunn, pp. 217-221.
[34] Andreas Persbo, May 2008.

Part II Conclusion

There are available techniques and technologies that could be used in verifying nuclear disarmament. Several serious challenges remain to be addressed such as how to deal with relatively low detection rates of fake warheads (in the region of 50–80 per cent) and intractable problems relating to material accountancy and control of unblended fissionable material. Over the last 40 years, several studies have concluded that it is probably unavoidable to conduct demonstrated dismantlement of nuclear warheads without revealing some sort of classified information. Most of this information is not related to the isotopic composition or mass of the fissionable material but rather to the nature of non-nuclear components. This paper has argued that it is not necessary to focus too much on non-nuclear component waste flows, which would in turn enable the inspected state party to put in place managed access regimes. These would seek to shield or shroud certain weapon components, or indeed equipment used in the dismantlement process, from the inspector resulting in a significantly decreased risk of proliferation sensitive information reaching the wrong hands.

Considerable attention has been devoted to the question *how to verify* nuclear weapons dismantlement, but rather less effort has been made to answer the question *who will verify* dismantlement. Bilateral arms control verification (primarily between the United States and Russia) will be sufficient for some time as weapons stockpiles transition from high numbers to lower.[35] Disarmament is expected, however, to turn into a multilateral effort, as numbers get closer to zero. In addition, non-nuclear weapon states may require more transparency in the dismantlement process, necessitating the involvement of non-nuclear weapon state inspectors under the guidance of a multilateral verification authority (such as the International Atomic Energy Agency).

Another question is how foolproof the verification regime needs to be. The majority view seems to be that verification requirements will become stricter the closer the numbers are to zero. The argument is that the military significance of one diverted warhead will be much higher if that is the last remaining warhead in the country's arsenal than if it is a single warhead in a state that is allowed to retain hundreds.[36] Admittedly, low numbers of nuclear weapons will only come about when the international climate is conducive to it. The transition to low numbers requires, some would argue, a fundamental shift in international affairs involving much greater degrees of trust between nations. If that argument is true, then the political context of disarmament verification would be fundamentally different than that of today's world. This could quite possibly mean that states would not require near perfect verification of the disposition of the very last warheads.

It is very difficult today to judge what the international climate would be in a world that contains but a hundred warheads. Most arguments and assumptions regarding verification tend to boil down to mere speculation. There is limited empirical data available to underpin any hypothesis since most disarmament cases (such as South

[35] At present the US and Russia controls over 90 per cent of the world arsenal.

[36] This is illustrated by the so-called Wiesner curve (named after President John F. Kennedy's scientific advisor Jerome Wiesner). For a discussion of this, see Acton, J.M. and Perkovich, G, *Abolishing Nuclear Weapons*, Adelphi Paper No. 396, IISS, London, 2008.

Africa, Iraq or Libya) have been too *sui generis* to contribute meaningfully to any workable thesis.

Some have argued that effective rights for whistleblowers are central for any effective monitoring of compliance with a zero-norm. The way in which Israel's nuclear programme was exposed to the world is sometimes viewed as the most likely way any future transgressor would be caught. Undeniably, strong civil society monitoring would play an important role in deterring violations. But this presupposes a vibrant civil society in monitored states. Repression of freedom of information, freedom of assembly, and freedom speech would severely restrict civil society monitoring.

The experience of the UK–Norway process not only shows that civil society organizations (in this case through VERTIC's involvement) may play an important role in influencing and reporting verification requirements. It also points to the importance of leveraging non-nuclear weapon state assets onto the verification problem. A careful reading of Article VI of the NPT shows that it is the responsibility of *all states to engage* in nuclear disarmament. This involves offering financial, technical or human resources to the nuclear weapon states, and to engage with them on the discussion as to how multilateral disarmament can be brought about.

This in turn points to the need for much greater verification training. At the moment there are few university courses, or indeed professional courses, on verification concepts, theory and practice. Those courses that are available tend to focus on how to carry out specific verification (such as IAEA safeguards training). Without context, verification activities tend to be less focussed. The solution is, to use an analogy, not to give the verification community a book or two to read but rather a map to the library, which would enable the community to focus its resources and to engage in truly creative thinking. Verification training would also help to build important trust between inspectors—it will enable the formation of personal relationships in addition to the more practical goals of educating the inspectorate on old and new technologies and health and safety aspects of the trade.