Part of a Pershing II missile being destroyed. Under the 1987 INF Treaty, more than 200 of these missiles were retired and destroyed. Photo: US Army.
1. Principles and Demands of Verification

A Nuclear Weapons Convention will only be effective if it can be adequately verified, both in political and technical terms. Verification is the process of establishing whether States parties are complying with their obligations under an arms control or disarmament agreement. Verification has several functions:

“First, it allows the parties to assess an agreement’s state of implementation. By establishing how each party is fulfilling its obligations, verification gives a good indication about the functioning of the agreement. Second, it discourages non-compliance with agreement provisions. Because parties know that breaches of obligations carry the risk of detection, they should be less inclined to attempt to renege secretly on their commitments. Third, verification can give timely warning of violation(s) of agreement conditions. In case of non-compliance, verification can reveal transgressions before these have a chance to turn alarming. Finally, by checking that obligations are indeed being honoured, verification helps generate confidence that the agreement and its verification mechanism are functioning as intended, thereby fostering trust and confidence between the parties.”

These four verification tasks - assessing implementation, discouraging non-compliance, timely warning, building confidence - are of particular relevance with regard to a potential Nuclear Weapons Convention. States parties need to implement the agreed process towards elimination and non-acquisition of nuclear weapons and allow other States to assess the effectiveness of this process. Since a few nuclear weapons can make a significant difference, violations of the obligations must be detected as early as possible and with high likelihood to discourage any State party from non-compliance due to unacceptable risks from responses of the international community. While punishment may only be applied in exceptional cases, verification of an NWC requires and contributes to an unprecedented degree of confidence and cooperation, which in itself is a value that discourages benefits from acquisition of nuclear weapons.

The Model NWC strives to prevent the construction of nuclear weapons and puts the technical barrier for diverting nuclear-weapon-usable material as high as possible, aiming at the detection and prevention of the illegal acquisition of nuclear weapons through production or removal of nuclear material from existing stocks. Verification of an NWC would monitor a wide range of nuclear-weapons objects (nuclear warheads and components, nuclear materials, equipment, facilities, delivery systems, command and control) and nuclear-weapons activities (research, development, testing, production, acquisition, deployment, stockpiling, maintenance, transfer, use, threat of use, destruction, disposal, and conversion) and their combination. These include, in particular, dismantlement of nuclear weapons; disposal of nuclear material; conversion or destruction of certain nuclear facilities; monitoring the location and status of nuclear weapons, nuclear material, nuclear facilities, delivery systems, and command and control systems to ensure that they are not used for research, development, testing, production, transport, deployment or use of nuclear weapons. Other prohibited activities would include storage, transfer and handling of nuclear weapons and fissile material. Some of these activities are easy to monitor (such as nuclear explosions), others require considerable detection efforts (such as finding hidden warheads).

Verification policies of the NWC should be designed to assure early detection and interpretation of information necessary for preventing prohibited activities or permitting timely responses to nuclear weapons development, involving a range of issues."
Perspectives on Nuclear Disarmament Verification

The 1996 Canberra Commission noted, “(b)efore states agree to eliminate nuclear weapons they will require a high level of confidence that verification arrangements would detect promptly any attempt to cheat the disarmament process.” (Executive Summary) According to the 1998 CISAC report of the U.S. National Academy of Sciences complete nuclear disarmament will, “require continued evolution of the international system toward collective action, transparency, and the rule of law; a comprehensive system of verification, which itself will require an unprecedented degree of cooperation and transparency; and safeguards to protect against the possibility of cheating or rapid breakout.” On the other hand, “even the most effective verification system that can be envisioned would not produce complete confidence that a small number of nuclear weapons had not been hidden or fabricated in secret. More fundamentally, the knowledge of how to build nuclear weapons cannot be erased from the human mind. Even if every nuclear warhead were destroyed, the current nuclear weapons states, and a growing number of other technologically advanced states, would be able to build nuclear weapons within a few months or few years of a national decision to do so.”

The stakes are high: “The verification and compliance regime for a nuclear-weapons-free world will need to be more effective than any disarmament arrangement hitherto envisaged. One hundred per cent verification of compliance with any international arms agreement is highly improbable. In the case of nuclear disarmament, however, the security stakes will be so high that states will not agree to disarm and disavow future acquisition of nuclear weapons unless verification reduces to a minimum the risk of non-compliance.”

However, these fundamental restrictions do not generally exclude verifiability of comprehensive disarmament, as Steve Fetter points out: “Although no verification regime could provide absolute assurance that former nuclear-weapon states had not hidden a small number of nuclear weapons or enough nuclear material to build a small stockpile, verification could be good enough to reduce remaining uncertainties to a level that might be tolerable in a more transparent and trusting international environment. And although the possibility of rapid break-out will be ever present in modern industrial society, verification could provide the steady reassurance that would be necessary to dissipate residual fears of cheating.”

This indicates the link between the verifiability of the NWC and its security environment. Accordingly, the Weapons of Mass Destruction Commission notes in its 2006 report: “One state’s non-compliance with its obligations under a treaty on arms control or disarmament may fundamentally and negatively affect the security of others. A bilateral treaty may simply be abrogated. In a global context, this may lead to collective reactions. Conversely, continued compliance with such treaty obligations impacts positively on security. In both cases, credible verification to establish compliance or non-compliance is of major importance.”

A viable regime should assure states at the very outset that participation provides a better guarantee of security than maintaining the nuclear option. A guiding principle should be the search for a regime sufficiently restrictive to ensure the highest level of confidence in compliance, but also sufficiently permissive to allow states to join without jeopardizing their legitimate security interests and commercial activities.

Requirements and Guiding Principles

To discuss the possible options and means for the verification of an NWC, it is useful to refer to some established general principles of adequate verification:

1. International law and its verification should enhance international security and
stability and avoid the risks of an unrestrained situation that could lead to arms races or war;

2. Verification is a comprehensive iterative process, with political, legal, diplomatic, economic, technical and military dimensions, for judging compliance with international law, containing the risk of cheating and increasing time for adequate response;

3. The verification process balances between those provisions that are to be verified (which degree of verification is tolerable) and those activities that can be verified (which degree of verification is feasible);

4. The demands, requirements and costs of verification are to be adapted to the relevance of specific treaty provisions and the associated risk of cheating, comparing the benefits and costs of additional verification measures;

5. Because existing verification means are not perfect, the residual risk needs to be reduced to tolerable levels by adequate responses, offsetting eventual military threats by and advantages for non-compliance.

Thus, the verifiability of a treaty is not an absolute issue, but a matter of degree depending on political assumptions and requirements as well as the available resources and capabilities for verification, which are not only technical. Most crucial is the question of “tolerable” degrees of verifiability and their associated residual risks.

For the early Reagan Administration, for instance, nothing short of 100 percent certainty that the Soviets were not cheating was tolerable. Since this was an impossible standard to achieve with limited verification efforts, the requirement prevented progress on disarmament. With Gorbachev, however, confidence and trust increased between the superpowers, and finally even Reagan accepted much lower verification standards in order to conclude the INF and START treaties. More verification was seen as too costly, and the residual risks were accepted because the potential security implications were perceived as manageable. It is remarkable to compare this with the [...] turn under the Bush Administration, which refused any verification provisions under the Moscow Treaty with Russia, failing to assert its demand for verification. Therefore, the nuclear disarmament process of the Strategic Offensive Reductions Treaty SORT remains undefined and does not build an infrastructure to implement and measure its success.

Between friendly nations, usually lower standards of verification are tolerable because the incentive for and probability of cheating are perceived as negligible. As long as there is a gap between verification demands and capabilities, either the capabilities must be improved, depending on the available means and resources, or the political requirements must be reduced to achieve the desired security gains by the treaty within the given resource limits. Thus, the verification process assesses the difference between the desired situation and the actual situation, and tracks the agreed path connecting both.

If the actual path diverges from the agreed path more than is tolerable, then the verification system should provide a timely alarm. Thus the following questions are to be considered for the verification process:

- Which agreed states, items and activities should be achieved, limited or prohibited during given periods with confidence and certainty (what are the requirements/tasks of verification)?
- Which verification means could be applied to monitor actual states and activities (what are the means of verification)?
- Can an intolerable deviation from agreed states, items and activities be detected in time with reasonable verification efforts (what are the benefits, costs and risks of verification)?

The requirements and tasks of verification are defined by the provisions of the NWC, specified by the definitions, and the agreed timeframe of their realization. The tasks of verifying these obligations can be divided into the following three main stages:
1. **Baseline information exchange and data gathering**: Identify the current status of the nuclear-weapons complex with reasonable accuracy without proliferating sensitive information.

2. **Disarmament**: Monitor the agreed path of reducing nuclear arms and eliminating the nuclear-weapons complex within tolerable limits of uncertainty and sufficient confidence.

3. **Prevent rearmament**: During the transformation to a nuclear-weapon-free world, and after it has been achieved, observe any objects and detect any activities that might indicate a nuclear-weapons capability.

The NWC needs to foresee a number of provisions that help to create the necessary confidence that the elimination of nuclear weapons is complete and will not be reversed. Verification of the following obligations is crucial:

1. **No nuclear weapons or relevant nuclear materials may be held back and hidden in the current nuclear weapons states.** The existing arsenals of nuclear weapons need to be disarmed completely. No single nuclear warhead and no significant quantity of nuclear-weapons-useable material may be retained. The process also needs to avoid a hidden inertia of the whole nuclear weapons production system.

   Verifying the dismantlement and destruction of remaining declared weapons, production and maintenance facilities is the easiest task of the verification system. The locations are known and the state of the facilities can be checked by on-site inspections. From the outset, member states would give a detailed inventory of their remaining weapons and weapons-grade fissionable materials. Affixed with a unique tamper-proof tag and seal, these would be stored in sealed containers and stored at secure locations, well away from potential delivery systems. Warhead pits would be removed to internationally monitored storage facilities to await final disposition.

2. **Nuclear weapons need to be “disinvented” to the degree achievable.** The whole infrastructure of the now existing nuclear weapons complex has to be dismantled. No research for or testing of nuclear weapons should be conducted. The knowledge of nuclear weapons experts should not be intentionally maintained, in particular the important specialized personal knowledge directly related to the design of weapons. Through these means, the threshold against reinvention of nuclear weapons can be significantly increased. Dual-use science and technology which is perceived as too important for civilian purposes to be banned needs to be controlled.

3. **A break-out of the ban to develop or manufacture nuclear weapons needs to be prevented and detected.** In any country that conducts nuclear power or nuclear research programs, the diversion of nuclear materials for nuclear weapon purposes needs to be prohibited and any related activity needs to be detected in time. Nuclear-weapon-useable materials should neither be produced for weapon purposes nor removed from existing stocks. Step-by-step, existing stocks have to be reduced down to zero. While old facilities are subject to monitoring and inspection, new production may occur at remote locations and at new, specially designed underground facilities that may be rather small and easy to hide. The risks of these activities can be reduced and the costs increased by a combination of remote monitoring from air and space, environmental sampling, and on-site inspections without a complete guarantee to detect such violations.

4. **No intention to acquire nuclear weapons should remain or have a reason to reemerge.** The international security system needs to provide clear evidence that nuclear weapons are inherently negative, and create incentives that make the possession of nuclear weapons undesirable.

   It is essential that compliance with these obligations can be sufficiently verified and universally and indefinitely enforced. Verification can significantly reduce the likelihood of breakout through a combination of deterrence and enhanced warning, but cannot completely assure that a small clandestine nuclear arsenal or hidden cache of plutonium will be discovered.
Iterative Verification Process

Verification is not a static one-time activity of monitoring that applies the above-mentioned means, but a dynamic, iterative process with four distinct phases of declaration, monitoring, inspection and enforcement being repeated successively and in parallel:

1. **Declaration and registration** provide the necessary information of the initial situation as a starting point for verification to allow comparison with future changes, either agreed or prohibited. All treaty-limited items are tagged, identified and registered, using advanced identification techniques (fingerprinting) without revealing sensitive design information.

2. **Monitoring** aims at detecting prohibited objects or activities. Continuous monitoring requires information gathering over periods of time. Remote sensors on satellites and aircraft provide monitoring of large areas to detect larger objects, in particular transport vehicles and buildings. The problem is to identify treaty-limited items among the vast number of existing civilian and military objects. However, regular cartographic mapping provides a basis [...] to detect irregularities/inconsistencies between official mapping information and actual remote sensing data.

3. **Inspection**: As soon as a suspicion of a treaty violation is raised, the inspection mechanism is applied to check whether it is justified or not. During visits to facilities, the inspectors could request all the necessary detailed information from the inspected party, including the opening of rooms, access to computer codes and interviews with personnel and neighbors. In addition, a wide range of non-destructive on-site monitoring devices at entrance/exit ports or along the perimeter of critical facilities (portal/perimeter controls) could be applied to understand the structure and function of equipment. Cooperation and consultation within the international agency could help in gaining and proving the information.

4. **Negotiation, prevention and enforcement**: If sufficient information has been gathered to indicate a treaty violation, negotiation and enforcement mechanisms could apply. The first step would be to demand that the suspected violator ends the prohibited activities or enters the destruction and conversion of prohibited objects. If the object or activity of concern is to be excluded from nuclear weapons use, additional preventive control measures are applied. If the suspected violator refuses any of these measures, a negotiation process is started, during which the motivations of the violator and the possible coordinated actions of the international community are explained. It would be important to leave the violator the option of a face-saving exit as early as possible. Ideally, enforcement measures should be preventive and minimally intrusive.

In the past, the iteration process has been incomplete. Neither remote monitoring and challenge inspections nor prevention and enforcement were adequate or possible under the safeguards system of the International Atomic Energy Agency (IAEA); the global spread of nuclear energy has made diversion for military purposes too easy. This explains the limited effectiveness of safeguards (see more in the following sections). Monitoring without inspection or enforcement can raise suspicions but not prove or prevent them. Therefore, more emphasis should be given to integrated mechanisms realizing all four tasks.
2. Political Mechanisms of Verification: Building on Existing Regimes

Political verification of an NWC will have organizational and societal requirements. Organizational means of verification include state, regional and international bodies as well as national legislation and bi- or multi-lateral arrangements. Societal verification means large-scale governmental and non-governmental participation in the implementation of an NWC. Such participation would be sought through affirmative obligations to report non-compliance and provide guarantees of protection for suppliers of information.

Each of the following examples has relevance to the functions and the forms of authority necessary for nuclear disarmament:

1. CWC: The Chemical Weapons Convention establishes a comprehensive framework for elimination of an entire class of weapons to be implemented through the Organisation for the Prohibition of Chemical Weapons (OPCW). It proposes, among other measures, a system for on-site inspections unprecedented in its intrusiveness. How successful this system is considered to be in promoting compliance and confidence will be instructive in considering the degree and type of intrusiveness to build into an NWC.

2. CTBT: The verification provisions of the CTBT suggest a system for gathering and processing information. The International Monitoring System under the supervision of the Technical Secretariat includes facilities for seismological, radionuclide, hydro-acoustic and infrasound monitoring. The Technical Secretariat is to store and process information through its International Data Centre on behalf of States Parties. Application of this model to an NWC would require, for example, review of the provisions for data receipt and initiation of requests for data to adjust for the security and transparency considerations particular to the nuclear weapons infrastructure.

3. INF/START: The Strategic Arms Reduction Treaties (START) and Intermediate-range Nuclear Forces (INF) treaties provide positive examples of bilateral verification procedures for nuclear disarmament. They shed light on the role of confidence-building and the ability to adjust for confidentiality concerns. The verification provisions of these treaties apply to delivery vehicles rather than warheads. New guidelines for verification of warhead dismantlement, removal of warheads from deployment and de-alerting would be necessary as next steps. A salient question in this context is the expansion of bilateral to multilateral procedures. This process must balance considerations of security, transparency, and confidentiality. Several studies have explored the verification of deep reductions in nuclear arsenals and the special requirements of elimination of nuclear weapons. One proposal for a “verification scheme for deep cuts” would begin bilaterally, incorporating the other nuclear weapon states (NWS) through transparency and confidence-building measures, leading to proportional or gradual reductions down to very low levels, in order to lay the foundation for eliminating nuclear weapons.

4. IAEA: In order to detect illegal activities, the NPT foresees nuclear safeguards on special nuclear materials to verify compliance. The IAEA safeguards regime is the primary model for accountancy, containment and surveillance of nuclear material. The officially declared intention of these safeguards is not to prevent diversion of such materials. The IAEA insists on not having a police function but only the role of inspection. The purpose of nuclear safeguards is the timely detection of diversion after it has happened. The detection should be made early enough to allow for political reactions aimed at stopping the proliferating country before a bomb is manufactured from the diverted material. However, the dual function of the IAEA—timely detection
of diversion and promotion of “peaceful” uses—makes its direct application to a
disarmament regime problematic. Because of unavoidable measurement uncertainties,
loss of material within facilities and lax practice, the IAEA safeguards material-
accounting system cannot with confidence detect the diversion of weapons size
quantities of nuclear material sufficient for the manufacture of dozens of weapons
(the limits became obvious in the case of Iraq). The task of differentiating between
military and civilian applications of nuclear material—widely though not unanimously
recognized as a primary source of IAEA shortcomings—will become more difficult if
reliance on nuclear energy increases. Some of the changes proposed in the IAEA 93+2
Programme and Additional Protocol reflect strategies and policies aimed at improving
the conditions for safeguarding.\textsuperscript{14}

\subsection*{Effectiveness of Nuclear Safeguards}

Safeguards in Nuclear Weapons States (NWS) are virtually non-existent, and the
IAEA does not have the mandate it needs to effectively prevent proliferation. Current
timely detection goals are faulty, and do not take into consideration the enhanced
nature of the technical means to turn fissile materials speedily into weapons. The fact
that the nuclear weapon states are only subject to selective voluntary scrutiny has
made it easier for them to share nuclear materials and designs; several have been guilty
of this practice. IAEA safeguards are currently not extended to apply fully to mined
uranium ores, refined uranium oxides, uranium hexafluoride and uranium conversion
facilities, prior to the stages of enrichment or fuel fabrication.\textsuperscript{14a}

One severe criticism of the current nuclear safeguards system is that it cannot even
achieve the limited goal of detection. At any large bulk handling facility, large amounts
of material unaccounted for (MUF) will inevitably occur. This problem is exemplified
dramatically with the publication of the US plutonium inventory for the first 50 years of
its nuclear program.\textsuperscript{15} While there is a current stockpile of about 100 tons of plutonium,
the amount of not less than 2.8 tons of plutonium is unaccounted for. This is enough
material for hundreds or even a thousand nuclear weapons. This raises a big concern;
Will we ever have the chance to gain enough confidence that no nuclear-weapons-
usable material is diverted by any country that possesses large amounts of such
materials?

Another severe criticism of nuclear safeguards is that clandestine nuclear weapons
programs are very difficult to detect. The experiences with clandestine nuclear weapons
programs in Iraq and other countries call for very strong and efficient verification
as long as nuclear installations with significant amounts of nuclear-weapons-
usable materials exist. The 93+2 Programme of the IAEA resulted in a number of
improvements that strengthen the effectiveness and improve the efficiency of the
nuclear safeguards system. However, the MUF-problem is not even tackled by these
measures and there will still remain deficiencies with other detection problems.

The question of capabilities and limits of technical verification depends on the
degree of political demands. The main purposes of nuclear safeguards on special
nuclear materials are timely detection of and deterrence against diversions of
significant quantities of these materials, i.e. they are not designed to prevent diversion
of such materials, but to deter from diversion by the risk of detection. Diversion
remains a technical possibility. With respect to a nuclear-weapon-free world such a
political goal may change. The demand may be posed that compliance with treaty
obligations is not only verified with a high probability of detection but also rendered
impossible especially through a strict reduction of the availability and accessibility of
nuclear-weapon-usable materials.

The experience of the IAEA in verifying South Africa’s nuclear inventory and
the termination of its weapons program is significant for developing and evaluating
the framework for verification of complete nuclear disarmament within the NWC.
By comparing calculations with physical inventory measurements, apparent discrepancies indicated that an amount of enriched uranium-235 was unaccounted for. Though extensive examinations were able to significantly reduce the magnitude of these apparent discrepancies, the IAEA had to conclude that the assessment of the completeness of South Africa’s inventory of nuclear materials was not free from uncertainty. Nevertheless, the international community was satisfied with the result of the investigations, which led to the conclusion that there were no indications that the initial inventory was incomplete or that the nuclear weapon program was not completely terminated. This positive conclusion is only possible because of the openness for transparency and the cooperation of the South African authorities with respect to access to information and past and future locations that allowed for further IAEA investigation.

The experiences with clandestine nuclear weapons programs in Iraq and other countries call for very strong and efficient verification as long as nuclear installations using, producing or storing significant amounts of nuclear-weapons-usable materials exist. Activities to strengthen the current regime include the following:

1. Despite the improvements of the 93+2 programme, which strengthen the effectiveness and improve the efficiency of the nuclear safeguards system, there are still deficiencies. In 1997, the IAEA introduced the Model Additional Safeguards Protocol with expanded safeguards authorities and activities. Not much has been achieved so far in providing the IAEA with technical means to detect clandestine activities from a distance. Satellite imagery is used mainly for investigations on known facilities and is not capable of providing a proof for clandestine plutonium production; environmental sampling is restricted to the locations that are routinely visited by inspectors anyway. Adopting and fully implementing the Additional Protocol increases the verification powers of the IAEA and expands transparency and verifiability for the whole civilian nuclear fuel cycle. It allows the IAEA to redirect saved verification resources towards states of greater concern.

2. UN Security Council resolution 1540 of April 2004 has made it mandatory for all states, including the three non-NPT parties, India, Israel and Pakistan, to adopt national implementation measures for all types of weapons of mass destruction to prevent non-state actors from acquiring or proliferating such weapons, either on its territory or elsewhere.

3. The Trilateral Agreement, negotiated 1996 to 2002 between Russia, the US and the IAEA, seeks to involve the Agency in verifying disposal of excess fissionable material and could give it a role in a multilateral global nuclear disarmament process. The agreement’s implementation has been hampered by the fact that no material has been offered by the US and Russia for the purpose; there is disagreement over the period and costs of IAEA monitoring.

4. The IAEA Board of Governors has established a Special Committee on Safeguards and Verification to examine further improvements, but it has moved slowly. For instance, the examination of environmental and other samples from Iran has not been as speedy as it might have been. More funding is required to conduct research in advanced nuclear verification techniques.

A breakthrough was expected since the mid-1990s on a fissile cut-off agreement, which has been prevented by the stalemate in the Conference on Disarmament in Geneva. Further progress is urgently needed as nuclear weapons development does not stand still. Laboratory testing, laser enrichment and computer simulation reduce the possibilities of driving back the knowledge about nuclear weapons development. With improved simulation technology, highly undesirable developments are possible that obstruct the goal of a nuclear weapons free world. At the end of an era of comparably primitive trial and error, a scientific revolution is now being initiated, which is supposed to deepen the theoretical understanding of nuclear weapons. Rather than deliberate and systematic conservation of knowledge about nuclear weapons, transition
to a nuclear-weapon-free-world would require retiring nuclear weapons scientists and testers to not transfer their expertise to future generations. Otherwise, it will be more difficult to “disinvent” sophisticated designs of nuclear weapons.

In a nuclear-weapon-free world not all use of nuclear materials may be banned. To prevent the diversion of nuclear materials for weapons development through the whole nuclear fuel cycle, from uranium mining and milling to disposition, nuclear safeguards would be needed. These would cover all nuclear materials in reactors, stockpiles or extracted from dismantled weapons, including those of the nuclear weapon states, to ensure that all sources of new fissionable material are accounted for. Consequently, the safeguards system would cover a considerably higher amount of material and a larger number of facilities than today. Completely banning weapons-usable materials would significantly facilitate the verification task. Allowing the use of HEU in naval propulsion would require special safeguards arrangements. Other ways in which safeguards would have to be further strengthened include increasing the intrusiveness of inspections, lowering the quantities and increasing the types of nuclear materials requiring declaration and inspection, and boosting the intelligence and data-handling capacities of the international verification organisation.20

A critical issue is the “significant quantity” of weapons-usable material required for nuclear weapons production. To provide greater assurance, the current standard (8 kg of plutonium, 25 kg of HEU) would have to be lowered and other nuclear materials identified as weapons-usable to be included. 3-4 kilograms of weapons-grade plutonium is commonly used for a nuclear warhead and, depending on the sophistication of weapons design, even significantly smaller quantities may suffice. Another issue is to lower the current standard for ‘timely detection’ from months to weeks which would better address the risk of rapid diversion from former nuclear weapon states.21
3. Means and Procedures for NWC Verification

Initially states rely predominantly on their national technical means (NTM) of verification and monitoring capabilities, including satellite monitoring, information gathering and espionage. In the process of moving towards a nuclear-weapon-free world a strong multilateral system of data collection and analysis capabilities needs to be established that complements or replaces national capabilities. All measures combined will reduce the risks and increase the costs of illicit activities to an actual or potential violator even though they may not completely guarantee the detection of such violations.

While the Model NWC bases many of its verification procedures on those employed in other treaties, new approaches are required. Remote and wide-area monitoring is a vital element of the verification regime as soon as the relevant production facilities are shut down and dismantled, especially if only a few sites remain to be inspected and efforts are more concentrated on detecting clandestine facilities and activities.

Technical verification means and processes have been continuously improving. Remote sensing from aircraft and satellites provides high-resolution images over large areas in short time. On-site inspections have to search for hidden warheads and related materials and to verify the shut-down of declared facilities. Challenge inspections are necessary to search for clandestine activities. To survey sensitive installations and activities, inspection authorities can make use of new cost-effective techniques without frequent intrusive visits. The inspections in Iraq stimulated the introduction of new methods such as environmental monitoring to detect releases around nuclear-related facilities and ground-penetrating radar. For example, atmospheric concentrations of krypton-85 can be used to get indications for clandestine plutonium separation from some distance. Authentication and fingerprinting techniques are based on the measurement of radiation emissions and other characteristic signatures.

To assure that the main obligations are adequately monitored and violations detected within tolerable limits of deviation, a variety of verification means and procedures can be applied, as listed in the following box. Some technical possibilities are principally available; others require additional research and development.

To address the technical challenges in verifying nuclear dismantlement, research, development and cooperation needs to be intensified on innovative techniques to monitor declared and detect undeclared weapons, facilities and materials. Most of the research in this area has been done in the US and the UK who have shared information on the results. In particular, the Atomic Weapons Establishment at Aldermaston has concluded a five-year program to study the dismantling of their Chevaline warheads to identify potential methodologies for a future nuclear disarmament verification regime. In 2005 the US National Academy of Sciences’ Committee on International Security and Arms Control (CISAC) published a comprehensive assessment of methods for monitoring nuclear weapons and nuclear explosive materials in a disarming world. The Committee concluded: “Current and foreseeable technological capabilities exist to support verification at declared sites, based on transparency and monitoring, for declared stocks of all categories of nuclear weapons—strategic and nonstrategic, deployed and nondeployed—as well as for the nuclear-explosive components and materials that are their essential ingredients.”

An effective NWC requires specific verification mechanisms that can discover clandestine nuclear-weapons-related activities with sufficient certainty, thereby increasing transparency and confidence in the whole nuclear disarmament process. In order to verify compliance with the NWC, a verification regime would be established with all the verification means and procedures explicitly needed to assure the verification of the NWC. The Model NWC seeks to lay out a verification regime to assure states that participating in this regime provides a better guarantee of security than maintaining the nuclear option.
The box opposite gives four categories of different readiness of verification technologies and provides a few examples for each of these categories. From this, it becomes apparent that most verification technologies required or proposed by the Model NWC are already implemented in existing treaties within the nuclear disarmament and non-proliferation regime. Some others are established in other international regimes and can be adopted for an NWC. In addition, there are further technological means which are already developed or demonstrated, but which are not yet implemented in any international control regime. Only very few verification technologies which may be helpful or necessary to verify an NWC are not yet developed or proven to work sufficiently. However, it has to be noted that most technologies have inherent deficiencies and need to be evaluated on a critical basis. That a variety of technical means for the verification of an NWC already exist does not imply that these means are covering satisfactorily all verification demands.

**Verification Means and Procedures**

1. **Monitoring technologies**
   - Remote sensors in the visible, infra-red or radar spectra, based on satellites, aircraft or on ground-based systems
   - Signal and electronic reconnaissance
   - Seismological, radionuclide, hydroacoustic and infrasound monitoring
   - On-site sensors for non-destructive measurement, e.g. for portal perimeter monitoring: measurement of weight, length, acoustics, light (UV, infrared, visible), electrical and magnetic fields; passive radiation measurement, active radiation (x-ray, gamma ray, beta particles, protons, neutrons)

2. **Cooperative procedures for information exchange, inspections and safety controls**
   - Nuclear archaeology and forensics
   - Initial declarations and data exchange
   - Identification and item counting of objects (tagging, fingerprinting, registration)
   - Confidence-building measures
   - Joint overflights (Open Skies)
   - Accountancy, control and surveillance
   - Safety Controls at nuclear facilities
   - Baseline and routine inspections
   - Challenge inspections of suspected facilities (anytime-anywhere)
   - Personal observation of destruction and suspected activities

3. **Institutional verification**
   - International Agency for Verification
   - Cooperative fact finding on compliance
   - Consultation
   - Dispute settlement

4. **Societal verification**
   - Open sources, scientific knowledge
   - Espionage
   - Citizen reporting and protection, whistle-blowing
### Availability of Verification Technologies

1. **Technologies which are already implemented in existing treaties within the nuclear disarmament and verification regime**
   - Nuclear material accountancy, limited by Materials Unaccounted For (NPT)
   - Containment and surveillance of nuclear materials (NPT)
   - Identification and item counting of objects by tagging, fingerprinting, registration (NPT and others)
   - Personal observation of suspected activities and destruction (NPT, INF, START)
   - Remote sensors in the visible spectrum based on satellites (INF, START)
   - On-site sensors for non-destructive characterisation of containers and transport vessels, e.g. for portal perimeter monitoring; measurement of weight, length (INF, START)
   - Seismological, radionuclide, hydro-acoustic and infrasound monitoring (CTBT)
   - Challenge inspections of suspected facilities without any restrictions, i.e. anytime and anywhere, limited by political acceptability and costs (UNSCOM)

2. **Technical approaches which are established in other international regimes and can be adopted for the NWC**
   - Preventive controls at nuclear facilities (Convention on Physical Protection)
   - Joint overflights with remote sensors in the visible spectrum (Open Skies)
   - Managed access (CWC)

3. **Technical means which are already developed or demonstrated, but not yet implemented in any international control regime**
   - Accounting, surveillance and containment of nuclear warheads, limited by access
   - Verification of dismantling of nuclear warheads, limited by the interest to protect sensitive design information
   - Remote sensors in the infra-red or radar spectra based on satellites, aircraft or on the ground
   - Passive radiation measurement, active irradiation using x-ray, gamma ray, beta particles, protons or neutrons, limited by free mean path depending on shielding of nuclear radiation (e.g. Black Sea experiment for the detection of hidden warheads)

4. **Technological options which need further research, development or demonstration of their capabilities and limits, before they can be adopted for the NWC**
   - Wide area radionuclide monitoring to detect uranium enrichment or plutonium separation (e.g. krypton-85)
   - Nuclear archaeology to reconstruct the working history of production reactors
4. Elements of NWC Verification

Some of the potential verification elements of the NWC are discussed in the following.

Registry and International Monitoring System

The Registry would maintain a list of all nuclear warheads, delivery vehicles, facilities, and materials subject to verification. The International Monitoring System enables the Agency to gather information necessary for the verification of the NWC and would comprise facilities and systems for monitoring by satellite, fixed on-site sensors, remote sensors, radionuclide sampling, means of communication and other systems. Information generated by equipment owned or controlled by member States would be shared through agreements with the Agency. Required are agreements on sharing data and verification activities with existing agencies, including those responsible for implementation of other treaties regarding nuclear disarmament. Methods of nuclear archaeology are important to reconstruct the past production history by investigating traces which are characteristic for the relevant past activities at production facilities and by doing model calculations.

On-site inspections and techniques

A challenge inspection system will be important to conduct on-site inspections, which may require an even more intrusive system than that of the Organization for the Prohibition of Chemical Weapons (OPCW) under the 1993 Chemical Weapons Convention (CWC). This would include both systematic, baseline inspections and challenge inspections (anytime-anyplace) of declared and undeclared facilities, utilizing a range of techniques, including visual inspection, record checks and non-destructive measurement (e.g., with portable x-ray and gamma-ray detectors). This could be assisted by identification techniques, such as tagging, tamper-indicating seals in nuclear power plants and “fingerprinting” of delivery systems. Perimeter portal monitoring systems would track the flow of items and materials relevant for nuclear weapons.

Preventive controls and nuclear energy

Due to unavoidable measurement uncertainties, loss of material within facilities and lax practice. As mentioned before, [ ... ] IAEA safeguards material-accounting system cannot with confidence detect the diversion of weapons size quantities of nuclear material sufficient for the manufacture of dozens of weapons, either by illegally producing nuclear materials, or by illegally removing nuclear material from existing stocks. The Model NWC strives to prevent the construction of nuclear weapons and puts the technical barrier for diverting nuclear-weapon-usable material as high as possible. Effective prevention would not be possible as long as weapons-usable nuclear material is available and can be diverted for use in nuclear weapons at any time. The above-mentioned problem of MUF leads to the conclusion that not only prevention but also the verification of the NWC would be very much facilitated by a significant reduction of the accessibility of nuclear-weapons-usable materials and production technology.

Therefore, the Model NWC demands the reduction of inventories as well as the reproducibility of nuclear-weapon-usable materials to the lowest possible level and proposes preventive controls on nuclear-weapons-usable material to guard against breakout of the ban to manufacture nuclear weapons. Preventive controls are
broader than IAEA safeguards, which are primarily intended to deter diversion of nuclear materials through detection of such diversion once it has taken place. The measures proposed in the Model NWC would concentrate on prevention of diversion through physical protection and restricted physical access to special nuclear material (containment and surveillance), increasing the risk and the cost for cheating and minimizing the risk for the international community. Preventive controls may include the establishment of procedures for transport, treatment, storage and disposition of such materials. By banning the technologies for production of direct use nuclear materials such as the reprocessing of spent fuel for separation of plutonium and by imposing other appropriate provisions the available quantities of nuclear-weapons usable materials are minimised. The inventories of these materials should be eliminated under international control as far as possible or converted into a physical form that minimizes access.

Recognizing the importance of declaring and monitoring all such material, the verification provisions allow for accountancy to begin even before entry into force of the Convention. In addition to the requirement that all special nuclear material be placed under strict, effective and exclusive international control, the NWC proposes to deal with long-term disposition of the fissile material through an optional protocol that would recognize disposition as an urgent problem and devote significant resources to the search for a permanent solution. Preventive controls will be international, eliminating national access to be eliminated to the extent possible. Nuclear-weapons usable materials in the civilian sector need to be included into preventive controls. An important step towards more effectiveness is the 93+2 safeguards agreement signed by IAEA members in May 1997. It includes expanded declarations, extended possibilities of inspection and techniques for environmental monitoring.31

In theory the highest barrier against breakout would be realised in a world without nuclear energy, which would exclude the infrastructure to produce nuclear weapons materials and would effectively foreclose any path towards the bomb. The NWC does not prohibit peaceful uses of nuclear energy, but it offers an optional protocol on energy assistance for States that choose not to develop or use nuclear energy. However, it should be pointed out that the abolition of nuclear weapons could be accomplished, though less easily, even without abolishing nuclear energy. The second best approach is to restrict the use of those nuclear technologies that have the highest relevance for nuclear proliferation and in addition to make the remaining special nuclear materials as inaccessible as possible for any country. Nonetheless, while the NWC verification measures will improve the existing safeguards system, they will face the same challenges in a world where reactors make bomb fuel.

Organizational verification and the implementing Agency

To implement the NWC and oversee the nuclear disarmament process, the Model NWC proposes an International Agency similar but not identical in structure to the OPCW. Its primary objectives include containment and surveillance of all materials, equipment, or facilities that could contribute to the development, production, or maintenance of nuclear weapons. The Agency would encompass and expand on some of the tasks currently within the mandate of the IAEA, which would be altered to focus entirely on verifying global disarmament, ceasing to facilitate the nuclear industry. The Agency in the Model NWC would have the following structure:

- The principal organ of the Agency would be a Conference of all States Parties, which would meet annually, and for special sessions as necessary;
- An Executive Council would be a standing body, to be elected by the Conference for a certain period. The EC would oversee implementation and operation of the Convention and would be responsible for day-to-day
decision-making on the operation of the treaty. It would also have the power to
demand clarification from any state party and recommend action in the case of
non-compliance. Membership would rotate, with attention to equitable regional
distribution and representation by nuclear weapon and nuclear-capable states;
• A Technical Secretariat, headed by a Director-General, would carry
out the tasks of implementation and verification through various mechanisms,
including a Registry and an International Monitoring System. Sources for
such information include declarations and reports by States, systematic and
challenge inspections, information from other agencies (including NGOs),
publicly available sources, national technical means, and the international
monitoring system.

An important component of the institutional process would be the reform of the UN
Security Council, which needs to represent nuclear and non-nuclear great powers to
delegitimise nuclear weapons and devise an effective and fair compliance system.

Transparency, education and confidence-building

The Model NWC makes transparency and education obligatory, in response to the
argument that nuclear weapons technology and knowledge cannot be uninvented.
The idea is to promote scientific responsibility and greater awareness of the link
between nuclear science and weapons development. Scientists can and should be
trained to identify and warn others of potentially prohibited activities. Confidence
building measures (CBMs) and supplying additional information on a voluntary
basis increases confidence in compliance with the Convention. CBMs could include
bilateral agreements on reciprocal monitoring and information sharing between States.
Consultation, cooperation and fact-finding should help to clarify and resolve questions
of interpretation with respect to compliance and other matters. These procedures
would be time-critical to ensure that essential evidence is not lost. Compliance and
enforcement provisions are linked to transparency and confidence-building measures
among States Parties. Dispute settlement provisions include negotiation, mediation
and referral to regional agencies or to the International Court of Justice (ICJ). The
Executive Council or Conference would also have the authority to refer unresolved
disputes to the ICJ for an advisory opinion and to the General Assembly or Security
Council.

All NWS need to contribute to improving the mutual nuclear transparency process.\textsuperscript{32}
This is a difficult task, partly because of concerns about confidentiality, partly because
of inherent uncertainties and poor bookkeeping from the beginning of the nuclear
era. Openess about past production of fissionable materials will be particularly
challenging, since it will be virtually impossible for any nuclear weapon state to give
a complete and accurate account.\textsuperscript{33} The documentation of past production (nuclear
archaeology) must begin now, while discrepancies are not strategically significant
and potentially destabilising. The sooner transparency can be achieved in relation to
numbers, types and deployments of nuclear weapons, delivery systems and holdings
of special nuclear materials, the earlier and deeper can confidence be established.
Activities could include exchange visits and cooperative monitoring ventures between
the nuclear weapon possessors.

Societal verification

Beside technical instruments, human information sources are increasingly relevant
for arms control verification. In addition to the governmental tasks in verification, new
possibilities of societal verification are created under the Model NWC which provide
citizens of all states with the right and the obligation to indicate suspected nuclear
weapons activities.\textsuperscript{34} Cheap and ready access to information and communication
technologies increases the possibilities for NGOs to participate in verification activities. Civil society, including non-governmental organisations (NGOs), professional bodies and individuals (such as academics, scientists and engineers), are involved in monitoring the activities of governments and if necessary can ‘blow the whistle’. Instructive cases are Mordechai Vanunu on the Israeli nuclear arsenal, Kamal Hussein on Iraq’s biological weapons program and various Russian defectors and whistle-blowers.

Societal verification would substantially extend the basis of information and add to the complexity of violating the treaty. It would also be a contribution to the protection and creation of democratic rights in all parts of the world. Organised societal verification is more feasible in open societies, but even in closed societies it would be difficult to prevent defectors from leaking critical information. Questions about the role and function of societal verification are particularly relevant to the future direction of nuclear research and development. The model NWC incorporates the concept of societal verification through individual rights and obligations, including citizen reporting and protection for whistle-blowers. According to Joseph Rotblat,

“The main form of societal verification is by inducing the citizens of the countries signing the treaty to report to an appropriate international authority any information about attempted violation going on in their countries. For this system of verification to be effective it is vital that all such reporting becomes the right and the civic duty of the citizen.”

Societal verification requires transparency and education. Scientists and nuclear industry workers should be alerted to the potential links between nuclear science and nuclear proliferation. This responsibility could be developed through training to identify activities that are, or border on, prohibited activities. Supplying additional information on a voluntary basis increases confidence in compliance. By definition, this approach is not the “Big Brother” model of suspicion and surveillance where citizens watch each other and the state watches all citizens, as some have suggested. Rather, societal verification aims for openness and trust in scientific and industrial endeavors. Indeed, secrecy and mistrust undermine the openness and free flow of ideas necessary for good science and its productive application.

In addition to the governmental tasks of verification, societal verification would substantially extend the basis of information and would be a contribution to the protection and creation of democratic rights in all parts of the world. NGOs could play an important role in this process. No state that secretly strives for nuclear weapons can be sure that persons involved in clandestine activities would not transmit their knowledge for a reward to the international community which then could take appropriate reactions.
5. Security Context and Challenges of NWC Verification

A precursor of a verification system for nuclear disarmament will be the US and Russian experience of verifying deep cuts, building on their [ ... ] extensive bilateral experience in verifying the INF and the START [ ... ] treaties. Valuable lessons have already been learned from existing regimes. On-site inspections can be managed in a way that does not reveal security or commercial proprietary information and some of the concerns disappear with progressing implementation and experience. Verification and transparency measures can learn from the cooperative threat reduction programs between Russia and the US to safely dismantle the former Soviet nuclear complex and control the fissionable material from dismantled nuclear weapons. Former nuclear scientists and facilities are employed in the disarmament process to prevent them from spreading their knowledge. This would also minimize the risk that personnel involved in verifying nuclear disarmament would acquire additional knowledge of nuclear weapons and thus contribute, inadvertently or deliberately, to proliferation.

The 2005 National Academies of Science (NAS) report has identified several issues that are critical for the monitoring of nuclear weapons and nuclear explosive materials (NEM): 39

- There are some tensions between sharing information about nuclear weapon and NEM stockpiles and maintaining the security of these stockpiles, but cooperative use of technologies can substantially alleviate these tensions;

- The characteristics of NEM and nuclear weapons place some fundamental limits on the capabilities of any system of monitoring and transparency to provide assurance of compliance. Accordingly, a degree of uncertainty is inescapable;

- The biggest challenge to cooperation-based verification would arise if countries give the appearance of cooperation while covertly retaining undeclared stockpiles of nuclear weapons or NEM and/or undertaking clandestine production programs;

- Important transparency measures do not necessarily require formal treaties but could be undertaken on the basis of informal understandings or unilateral initiatives, e.g. as part of broader confidence-building efforts;

- There are both liabilities and benefits of incorporating, in the long run, nuclear transparency and monitoring into formal agreements to address complexity and sustain measures over time;

- The synergistic effect of the discussed approaches in a cooperative environment, coupled with robust NTM capabilities, would substantially reduce current uncertainties over time.

The report also makes clear that in view of the sheer size and age of the Russian stockpile (where current uncertainties are equivalent of several thousand weapons), “Russia probably could conceal undeclared stocks of several hundred weapons”. For other countries with much smaller programs, absolute uncertainties would be much less, leading to the possibility that “these countries could conceal undeclared stocks equivalent to one or two dozen weapons in the case of China, and at most one or two weapons in the cases of Israel, India, and Pakistan.” However, “confidence that declarations were accurate and complete, and that covert stockpiles or production facilities did not exist, would be increased by the successful operation of a monitoring program over a period of years in an environment of increased transparency and cooperation.”

The security impact of breakout scenarios would depend on the particular circumstances, including the state of readiness and deliverability of weapons; the existence of defenses; the relative military strength of the violator; and the international
community’s willingness to respond (Findlay 2003). Illicit nuclear weapons produced, “would be untested, could not be deployed until the last minute, could probably not be delivered by conventional means, and overt training for use would have been impossible.” Of course, such a scenario is not only possible in a nuclear-weapon-free world, but also more likely in today’s nuclear-armed world, and it may be or may not be deterred by the existence of other nuclear weapons. An actor (whether governmental or non-governmental) threatening to use such a weapon would provoke others to rebuild a nuclear device or arsenal, thus loosing the temporary advantage.

This highlights the fact that verifiability of a NWC depends on political assumptions and requirements as well as on the available resources and capabilities for verification, which are not only technical. A bargaining process is necessary between political demands and technical capabilities. If political demands increase, the technical solution may become more expensive. If technical or economic limits for introducing advanced or improved verification means are reached, political demands are either cut back or need to be satisfied by non-technical measures. For example more intrusive measures of physical protection and control can be introduced which go beyond verification of compliance with treaty obligations.

Although there may never be a foolproof multilateral verification system for total nuclear disarmament, the limits of technical verification must not lead to the pessimistic view, that a nuclear-weapon-free world and an irreversible path towards that goal is not adequately verifiable. Instead, the political consequence of this merely technically induced evaluation is to find strategies to increase the barrier against a first or renewed access to nuclear weapons. Given their limits, verification of an NWC would not only rely on technical measures. A number of means and procedures can be applied to detect clandestine objects and activities and clarify critical questions. How well these elements can be integrated into a coherent and effective verification system for a Nuclear Weapons Convention requires further examination.

As Trevor Findlay (2006) points out, “complete nuclear disarmament implies not just a significant evolution in verification, but an evolution of the international system. States will have to change their attitudes towards the limits of sovereignty, the rule of international law and governance of the international system, particularly in regard to enforcement, if nuclear disarmament is ever to be negotiated. Indeed, the attainment of a nuclear weapon free world is so dependent on such changes that we will only be able to judge fully and accurately its verifiability as we become seriously engaged in moving towards that goal.”

Endnotes to Section 4


Trevor Findlay, Verification of a nuclear weapon-free world, VERTIC Briefs, May 2003.

Fetter 1996.


Kalinowski, Liebert, Scheffran 2000.

Findlay 2003.

Tom Milne, Henrietta Wilson, Verifying the transition from low levels of nuclear weapons to a nuclear-weapon-free world, VERTIC Research Report, no. 2, June 1999, p. 17 ff.


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Fetter 1996.

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Source: Kalinowski, Liebert, Scheffran 2000.

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After a discussion in the Drafting Committee in November 1997 the term “preventive controls” has replaced the term “Safety Controls” used in the original Model NWC.

Similar proposals have been put forward earlier. See especially Lisbeth Gronlund and David Wright, Beyond Safeguards: A program for more comprehensive control of weapon-usable fissile material, report by the Union of Concerned Scientists, Cambridge, May 1994. This report defines type 1 controls which limit the production and use of fissile material for weapons or outside of safeguards, and type 2 controls which limit the production and use of weapon-usable fissile material for all purposes, including civil purposes that are safeguarded, and the operation of facilities that can produce weapon-usable fissile material.


33 Findlay 2003, p. 10.
37 Model Protocol Additional, IAEA, INFCIRC/540, Vienna, September 1997
39 NAS/CISAC Committee 2005.