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# Verifying nuclear arms control and disarmament

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From the outset verification has been an essential element of attempts to control the nuclear arms race. This chapter assesses what has been accomplished in nuclear verification and compares it to the requirements for achieving comprehensive nuclear disarmament and for the maintenance of a nuclear weapon-free world.

Verification of a nuclear weapon-free world consists of two separate tasks: establishing with sufficient confidence that former nuclear weapon possessors have completely destroyed their arsenals and production capacities; and creating sufficient confidence that a world free of nuclear weapons will remain so.[1] Verifying nuclear reductions is a simpler task than verifying the transition to zero, since the latter must ensure that no clandestine nuclear arsenals remain and that all production complexes have been destroyed or converted. For both tasks some rudimentary elements are already in place or soon will be.

The first steps towards a nuclear weapon-free world comprise reductions in the number of nuclear warheads. The technical processes required encompass many individual initiatives, some of which are already being implemented as part of existing treaties, namely deactivation measures, separation of warheads from delivery vehicles, destruction or conversion of delivery vehicles and launch systems, and the destruction of missile silos. Others are taking place voluntarily, such as the destruction of warheads. Until now these latter steps have not been verified, although they could be integrated into future disarmament treaties. One of the last moves would be the disposition or re-use of fissile material retrieved from nuclear weapons for non-military purposes.

Treaties that limit or reduce nuclear weapons are: the 1972 Strategic Arms Limitation Talks (SALT) I Interim Agreement; the 1979 SALT II agreements; the 1987 Intermediate-range Nuclear Forces (INF) Treaty; the 1991 Strategic Arms

Reduction Talks (START) I Treaty; and the 1993 START II Treaty. All of these are bilateral agreements between the US and the Soviet Union or Russia.[2]

As the objectives of these treaties have become successively more ambitious, so too have the accompanying verification measures. The verification arrangements for the early treaties seem modest by today's standards, but they represented a major advance at the time. Negotiations are likely to begin soon on a START III Treaty, which has been under discussion since the Helsinki Summit in March 1997 between US President Bill Clinton and then Russian President Boris Yeltsin.

SALT I set upper limits for land-based and sea-based strategic nuclear missiles. There were two major components to its verification system: national technical means (NTM); and co-operative measures. The former—'consistent with recognised principles of international law'—were understood to mean the use of satellite imagery, aircraft-based reconnaissance (for example, employing radars and optical cameras), and sea- and ground-based monitoring systems. These are operated unilaterally and non-intrusively, being located entirely outside the other party's territory. To enhance confidence in verification, Washington and Moscow agreed to renounce deliberate concealment of, and not to interfere with, each other's NTM.

They also agreed to co-operative measures, including information exchanges and the establishment of a Standing Consultative Commission (SCC). The SCC's task is to clarify differing interpretations of the treaty's provisions and ambiguous situations, consider additional arms control measures, evaluate changes in the strategic situation, and to promote further development of verification. Although the SCC has no monitoring function itself, it has the important job of raising confidence through consultation.

The priority given to NTM and co-operative but non-intrusive measures is typical of arms limitation agreements concluded in the early 1970s. The Soviet Union feared intrusiveness, and the negotiations would have failed had the US insisted on on-site inspections (OSIs). These were hardly mentioned during the talks, and their advantages were not investigated. Since permissible verification means were constrained, so the scope of the treaty was correspondingly limited. While missile launchers were visible using national satellite capabilities, delivery systems were not. Consequently, SALT I froze the number of strategic missile launchers, but not of delivery systems. Similarly, sea-launched cruise missiles (SLCMs) were left unconstrained because their limitation was considered too difficult to verify at the time.

SALT II was more progressive. It set additional limits on several classes of strategic nuclear delivery vehicles. Although the basis of verification was (again) NTM, together with a SCC, its functions were expanded. More detailed and regular information exchanges, specific evaluation and counting rules, and notification of flight tests were agreed. The role of the SCC became more complex. For example, it was charged with developing agreed dismantlement procedures. What were still lacking, though, were co-operative verification procedures. US President Ronald Reagan's administration was suspicious of the SCC's ability to resolve charges of non-compliance, relying instead on making them public. The effectiveness of the treaty mechanisms for resolving disputes was thus seriously undermined.

The verification regime for the INF agreement was much more impressive and intrusive. It eliminated an entire category of weapons—all land-based nuclear missiles with ranges between 300 and 3,400 miles—as well as launchers, and support structures and equipment. It also banned production and flight-testing. As the prohibited systems were small and easy to conceal, non-intrusive measures were no longer sufficient. Since an entire class of weapons was to be eliminated, the verification task was to detect a single prohibited missile or launcher. As a result, OSIs were introduced for the first time—in addition to notifications and NTM. Such intrusiveness was unprecedented. The OSIs included:

- routine inspections at specified sites;
- inspections to verify the elimination of systems;
- 'close-out' inspections to verify the cessation of production; and
- continuous monitoring of portals.

Technologies that could be used included sensors, surveillance systems, measuring equipment to monitor traffic and x-ray imaging. In addition, short-notice inspections were to be permitted to enhance the probability of detecting non-compliance. As in previous treaties, NTM were allowed, complemented (again) by rules prohibiting non-interference. Co-operative measures, such as each party's right to request the open display of road-mobile ground-launched ballistic missiles six times per year, were more wide-ranging than before.

A Special Verification Commission was established to promote the objectives and implementation of the Treaty. It was authorised to resolve questions relating to compliance and to determine measures to improve the effectiveness of the accord. The verification experience was judged a major success by both sides, and as a result, acceptance of OSIs has increased substantially. Nevertheless, it was also recognised that OSIs have their limits and that they are not able to provide complete assurance. On-site inspections with no right of refusal would have been more effective than those provided for, but fears of possible leaks of sensitive information remained too high to reach agreement on them.

More progress was made with START I, which mandated deep cuts in American and Soviet strategic arsenals (although it did not eliminate whole categories of such weapons). Its verification provisions exceeded previous achievements. They included the use of NTM, transparency rules, such as a ban on encryption of telemetric measurements during test flights, co-operative initiatives, like open displays of road mobile launchers, notification of various activities, and a large variety of inspections and continuous monitoring. Inspections were to be conducted to verify baseline data, information updates, establishment of new facilities, and suspect sites. Re-entry vehicles of deployed intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) could also be inspected to corroborate that they contained no more re-entry vehicles than the number attributed to them.

Following dispersal exercises, inspections could also be made of deployed mobile ICBM launchers and their associated missiles to authenticate quantities. Conversion, elimination and 'close-out' inspections could be conducted to validate that the eradication of facilities was complete, while inspections could also be carried out at declared former plants to ensure that they had not been re-commissioned. In addition, technical characteristics exhibitions were required, at which the other party had the right to conduct inspections of ICBMs, SLBMs, bombers, cruise missiles and mobile launchers to substantiate that technical characteristics corresponded to specified data. Moreover, continuous monitoring of production facilities for ICBMs and mobile launchers was permitted to confirm that no more than the allowed number was produced. A Joint Compliance and Inspection Commission (JCIC) was set up to resolve questions relating to compliance and to agree on additional measures to improve the application of the Treaty.

START II brought more progress in substance, mandating even deeper cuts, and, most extraordinarily, eliminating all ICBMs with multiple independently targetable re-entry vehicles (MIRVs).[3] Its verification provisions are the same as for START I. But the Treaty covers only delivery vehicles, not nuclear weapons themselves. Both sides still believed that measures necessary for warhead dismantlement would be far too intrusive.

## Verification of warhead dismantlement

The treaties described so far have served to limit the nuclear arms race and have achieved reductions. Should the process continue, verification must, sooner or later, deal with warheads themselves. At their 1997 Helsinki Summit, Clinton and Yeltsin announced that a START III treaty would include destruction of nuclear warheads and the promotion of warhead transparency.[4] It is also likely that verification measures relating to the dismantlement of warheads will be included in START III. This would be unprecedented and an indispensable step towards a verifiable nuclear weapon-free world.

If nuclear disarmament is to proceed further, a variety of verification and transparency measures for nuclear warheads is indispensable. These measures will have the following objectives:

- to identify warheads and distinguish them from fakes;
- to monitor warheads permanently, particularly during transport from place of deployment to an intermediate storage site, and from there to a dismantlement facility—until completion of the destruction process, there must be assurance that declared warheads cannot be exchanged for fakes; and
- to verify destruction—there must be assurance that no intact warhead leaves a dismantlement facility.

The main difficulty with more intrusive verification of warhead dismantlement and destruction is the desire on the part of the nuclear weapon states (NWS) to maintain secrecy. This has several purposes:

- to avoid disclosure of the technical details of warhead design and construction, which would pose dangers for nuclear non proliferation; it could also conflict with the commitment of the NWS in Article I of the 1968 Nuclear Non-Proliferation Treaty (NPT) not to transfer nuclear weapons or the means by which they might be manufactured to non-nuclear weapon states (NNWS);
- to hide their level of technological development, whether weak or superior;
- to avoid any damage to national prestige.

The first two purposes, in particular, must be taken into account in designing verification and transparency measures. The third might become insignificant with time, especially if suitable political initiatives lead to greater openness. But continuous resistance to such transparency from the scientific and military communities involved in nuclear weapon research, development, production and maintenance must be expected over a long period. Clear variations in the degree of secrecy can be seen among the NWS, which can largely be explained by tradition. The highest degree of openness is in the US.[5]

While OSIs and permanent monitoring must become more intrusive in order to achieve verification goals, they must also be designed to protect sensitive data. Since 1996 there has been bilateral technological co-operation between Russia and the US in studying verification of the destruction of nuclear warheads. The results were discussed at the Helsinki Summit, but have not yet been published.[6] There are many additional studies dealing with technical verification methods,[7] some focussing on technical applications.[8]

Most studies assume that warheads will be placed in sealed containers prior to the dismantlement process. Since a warhead contains radioactive material, it emits radioactive radiation that is characteristic of its type. The radiation depends on the kind of nuclear material and the absorption characteristics of the warhead materials, as well as the additional shields of the container and their geometric distribution. In the simplest case, the released radiation can be measured despite the shields (so-called 'passive detection'). In certain cases, this is insufficient, and radiation that can be measured from outside must be induced by 'active' measures, such as neutron bombardment. X-raying is also an active detection measure.

A measured radiation spectrum is known as a 'fingerprint'. In a verification scenario, fingerprints of all types of warheads will first be recorded. Then every further measurement of a warhead in a sealed container can be compared to these records, so that identification of the warhead is possible without opening the container and revealing proliferation-relevant information. It would also be possible to distinguish real warheads from fakes.

Fears have been expressed, however, that this method would still reveal too much secret information.[9] Chinese analysts have raised this objection, but have offered a technical solution. They claim that the identification of warheads would still be possible if only a small part of the spectrum was revealed. A further possibility would be largely to automate the process with the aid of 'sealed' computer programmes. A fingerprint with such a masked spectrum would be taken for reference, and the information fed into a computer. This method requires no further involvement by inspectors, provided the software and anti-tampering measures ensure that the programme cannot be manipulated.

In order to guarantee that real warheads—and not fakes—are destroyed, the warheads that have been identified must be delivered to a dismantlement facility in the sealed containers with assurance that they have not been opened.[10] The exit must also be checked so that no warheads can be removed intact. The inside of the installation can remain closed to inspectors. Once the non-nuclear components have been destroyed they can no longer reveal sensitive information. The final stage of the dismantlement procedure is to deal with the radioactive 'loose material' —uranium and plutonium—which must be recorded at the exit. As long as strict monitoring ensures that no nuclear pits and loose material are diverted, it is not necessary to know the amount of material contained in a specific warhead. But an average figure would be helpful.

## Verifying comprehensive nuclear disarmament

It would be a major achievement if START III established such a verification regime. For the verification of comprehensive nuclear disarmament, however, the process would have to go even further. The scenario described above would be well suited to verifying dismantlement and destruction of declared numbers and types of warheads. For comprehensive nuclear disarmament, a high probability of detecting *undeclared* warheads is also indispensable, so as to create assurance that no clandestine arsenals are being maintained. An important prerequisite would be much higher transparency regarding existing arsenals, such as a comprehensive overview of all existing warheads, including tactical nuclear weapons, which, to date, have not been subject to any arms control treaty.[11] A 1993 proposal by then German Foreign Minister Klaus Kinkel for a nuclear weapons register at the United Nations should be revived.[12]

The disarmament treaties described so far are bilateral agreements. Indeed, the nuclear reductions that have been agreed and will be negotiated soon, involve only the holders of the two largest arsenals, Russia and the United States. At least all of the declared NWS and additional unofficial nuclear weapon possessors must be involved in the final moves towards nuclear disarmament. The Treaty and its verification system must be multilateral, requiring a different organisation, decision-making procedures and compliance mechanisms. A major exemplar of a multilateral verification organisation is the Vienna-based International Atomic Energy Agency (IAEA). Nevertheless, valuable technical lessons can also be drawn from the bilateral treaties.

The task of detecting undeclared warheads cannot be undertaken solely with technical means. These can be employed when concrete evidence exists of undeclared warheads: specially trained inspectors with the relevant equipment would be able to find and catalogue warheads at an identified location. But there is no guarantee that such evidence will ever manifest itself. The following elements would, however, be important in increasing the possibility of detection:

- the highest possible level of transparency regarding production histories, above all declarations and documentation, the publication of historic documents and the possibility of interviews with former employees;
- full exploitation of all relevant technologies, particularly aerial reconnaissance and environmental measurements, and the full range of NTM, including intelligence gathering;
- freedom of the press and a democratic climate, which should generate a sense of obligation on the part of individuals involved in illegal nuclear weapons activity to 'whistle-blow';
- the possibility of enforcing a multilateral verification authority's demand for clarification in the case of suspicion, through mandatory challenge inspections; and
- increased international trust, resulting from positive experiences of verification.

Taken individually, each of these factors is important for the verification of total nuclear disarmament. Together, they would improve verification to such an extent as to constitute 'sufficient criteria' for effective verifiability. It would be unrealistic to expect the verification of comprehensive nuclear disarmament to be achieved in one step, but it is realistic to expect each successive step to build on past experience.

## Verifying the absence of clandestine nuclear programmes

Once a nuclear weapon-free world has been achieved, permanent verification would be necessary to provide assurance that clandestine nuclear weapon programmes could be detected early enough for countermeasures to be taken. The five factors listed in the preceding section are equally important to continuing verification of a nuclear weapon-free world.

Treaties that ban the possession of nuclear weapons already exist, namely the NPT and several agreements creating nuclear weapon-free zones (NWFZS).[13] The

IAEA effectively verifies the NPT and the NWFZs through its system of full-scope safeguards.[14] In addition, there is one regional safeguards agency, EURATOM, which includes all members of the European Union, and one sub-regional system, the Argentina–Brazil Agency for Accounting and Control of Nuclear Materials (ABACC). These systems can play a crucial role in raising acceptance of IAEA safeguards. ABACC is an important example of the remarkably positive role that a regional safeguards system can play in non proliferation: within a few years, strong suspicion about and between the two countries has been replaced by confidence in their peaceful intentions. The negotiation of an NWFZ could be the vehicle for nuclear disarmament of one or more participating states, as has frequently been suggested for the Middle East.[15] A nuclear weapon-free world can only become possible when the security problems of such regions are resolved. An advantage of an NWFZ, compared to the NPT, is the possibility of making them non-discriminatory.

Measures that detect clandestine programmes—in addition to verifying declared materials and activities—are an indispensable prerequisite for verification of a nuclear weapon-free world. Prior to the safeguards reform instituted after Iraq's violation of the NPT, IAEA safeguards concentrated on verifying compliance with declared commitments and neglected the detection of undeclared activities. The reform introduced many measures that strongly increase the chance of early detection of a violation.[16]

This task is most difficult in the NWS. The IAEA safeguards in the NWS are voluntary, and only a small number of facilities are currently subject to them. The civilian nuclear fuel cycles of France and the UK are at least subject to EURATOM safeguards, although they have the right to withdraw facilities and materials from safeguards for defence needs.

## Next steps

If nuclear verification is to develop in preparation for a nuclear weapon-free world, more binding measures need to be introduced for the NWS. The aim should be to have a universal safeguards system, applying equally to NWS and NNWS.[17]

### *A Fissile Material Cut-off Treaty*

A Fissile Material Cut-off Treaty (FMCT) would serve as a good starting point for the extension of safeguards in the NWS.[18] It has been on the disarmament agenda for several years, although very little progress has been made. It has become a symbol for further advancement towards nuclear disarmament, but its most important benefit would be to introduce increased verification measures in the NWS. Its verification task would be to provide assurance that no state party was producing or diverting nuclear material for weapon purposes. This is almost the same as the verification of compliance by NNWS with their obligations under the NPT. It is not clear, though, whether the Treaty will cover only future production of weapon-usable materials or previously produced materials, too. Theoretically, verification should be the same as for full-scope IAEA safeguards. But some of the NWS do not seem to agree: their verification proposals envisage much more limited measures, such as verification of only the most sensitive facilities. Even these proposals, however, would set precedents and create an important basis for future developments. Verification at former production facilities would be a major milestone, and the experience gained would create additional confidence.

### *The Trilateral Initiative*

A positive step towards increased nuclear verification in the NWS is the trilateral process between Russia, the US and the IAEA. Under the initiative, excess nuclear materials from disarmament are submitted to verification. The task is to provide assurance that steps taken to deal with nuclear materials when reducing nuclear arsenals are irreversible.[19] Negotiations that have taken place since 1996 have been slow. There are differences over how to provide assurance that plutonium to be stored in storage facilities is of weapons-origin,[20] as well as concern about protecting sensitive information from international inspections. In Russia, much technical data that would be needed if safeguards were applied are classified, such as the isotopic composition of weapons-origin plutonium. And at many of the facilities involved, such as former nuclear weapon production sites, much proliferation-relevant information could be revealed if verification measures were too intrusive. Some of the security arrangements for access and inspections will be very different from those encountered elsewhere.

Nevertheless, in 1998, substantial progress was made in developing and testing verification equipment.[21] So-called 'information barriers' have been jointly developed that prevent access to classified information, but, at the same time, seem to satisfy verification needs. This new role for the IAEA is unprecedented and may trigger additional efforts to make nuclear facilities more safeguards friendly. It is also a necessary first step towards the goal of full-scope safeguards in the NWS.

### *Other transparency measures*

Declarations of intent to allow IAEA controls on excess nuclear weapon materials can be found in the statement of the 'P8' countries at the 1996 Moscow Summit,[22] in several co-operation projects between various countries and Russia, and in the Plutonium Management Guidelines agreed among plutonium user countries. As a transparency initiative, the US started, in 1993, to publish estimates of its plutonium stocks. The UK has also begun to publish estimates of its stocks and declared its intention to submit excess plutonium to IAEA inspection.[23] But its excess highly enriched uranium (HEU) for nuclear submarines will be retained outside safeguards.

In the longer term, it will be necessary to have more fundamental safeguards reforms—to achieve a universal system without distinction between the NWS and the NNWS. Such a future system must be characterised by a new safeguards culture, based more on qualitative and political judgements than schematic, quantitative measures. Reform will have to address: finances; organisation; decision-making; effectiveness; measures to deal with non-compliance; and underlying principles, such as the amount of nuclear material considered to be a 'significant quantity' in weapon terms. Reform will become necessary even without an FMCT because of the various non-proliferation and disarmament problems requiring new solutions. Such a global approach could lay the ground for a nuclear weapon-free world.

## Conclusion

Total nuclear disarmament will only become possible after many intermediate steps have been taken. But each prepares the next, and will change both the security and security perceptions of the states involved, thereby influencing their subsequent decisions regarding further moves. In each phase, what is possible or impossible will be defined anew. The experience gained will also affect verification. An essential prerequisite for each new step is the enhancement of transparency and trust, and, as a result, trust in verification will also need to grow. It is wise, therefore, to design verification as if a nuclear weapon-free world is the objective, even though a decision as to whether it should become reality may be delayed.

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# Endnotes

[1] The many studies that deal with verification of a nuclear weapon-free world include: Annette Schaper and Katja Frank, A Nuclear Weapon Free World – Can it be verified?, *PRIF Reports*, no. 53, Frankfurt, December 1999; Steve Fetter, Verifying Nuclear Disarmament, The Henry L. Stimson Center, *Occasional Paper no. 29,* October 1996; Frank von Hippel and Roald Z. Sagdeev, *Reversing the Arms Race—How to Achieve and Verify Deep Reductions in the Nuclear Arsenals,* Gordon and Breach, New York, 1990; and Christopher E. Paine, Thomas B. Cochran and Robert P. Norris, Techniques and Procedures for Verifying Nuclear Weapons Elimination, *Background Papers of the Canberra Commission on the Elimination of Nuclear Weapons,* August 1996, p. 167. VERTIC has published a series on verification of a nuclear weapon-free world: Patricia M. Lewis, 'Laying the Foundations for Getting to Zero: Verifying the Transition to Low Levels of Nuclear Weapons', VERTIC *Research Report,* no. 1; Tom Milne and Henrietta Wilson, 'Verifying the Transition from Low Levels of Nuclear Weapons to a Nuclear Weapon-Free World', VERTIC *Research Report,* no. 2; and Suzanna Van Moyland, 'Sustaining a Verification Regime in a Nuclear Weapon-Free World', VERTIC *Research Report,* no.4.

[2] START II was negotiated bilaterally by the Soviet Union and the US. It was subsequently multilateralised to include Belarus, Kazakhstan and the Ukraine, where former Soviet nuclear weapons were stationed.

[3] START II was ratified by the Russian Duma on 21 April 2000. The next step required for the Treaty to enter into force is US Senate approval of American ratification of the 1997 agreements that amended the Treaty. This has been the prerequisite for US willingness to start negotiations on START III.

[4] President Clinton and President Yeltsin, Joint Statement on Parameters on Future Reductions in Nuclear Forces, *White House Fact Sheet,* Helsinki, 21 March 1997. Printed in full in *Disarmament Diplomacy,* April 1997, p. 32. A START III treaty should contain, among other things, 'Measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads . . .'.

[5] At the end of 1993, as part of the policy of 'openness', the US Department of Energy began an initiative to reform transparency in government. On 29 June 1998, a new directive on classification came into force, incorporating the advice of several advisory panels. See Department of Energy, Office of the Secretary, 10 CFR Part 1045, RIN 1901-AA21, Nuclear Classification and Declassification, Action (Final Rule).

[6] The partners in this are the Sandia National Laboratory (SNL) and the Russian Federal Nuclear Center–All Russian Research Institute of Technical Physics (RFNC–VNIITF). The latter is a research laboratory in Snezhinsk (previously known as Chelyabinsk-70), which was responsible for research and development of new nuclear weapons. See Oleg Bukharin and Kenneth Luongo, 'U.S.-Russian Warhead Dismantlement Transparency: The Status, Problems, and Proposals,' *PU/CEES Report,* no. 314, Center for Energy and Environmental Studies, Princeton, NJ, April 1999, and Nikolai F. Rubanenko, 'Nuclear Weapons Transparent Dismantlement', paper presented at the International Pugwash Workshop, 11–13 September 1997, Snezhinsk, Russia. There is a volume with approximately 50 technological contributions from a conference involving both research institutions, held from 18–22 August 1997. To date, this has only been made available to the US and Russian governments.

[7] Examples include: Christopher E. Paine, Thomas B. Cochran and Robert P. Norris, p. 167; Natural Resources Defense Council, *Report on the Third International Workshop on Verified Storage and Destruction of Nuclear Warheads,* Moscow and Kiev, 16–20 December 1991; Federation of American Scientists and Natural Resources Defense Council, *Report on the Fourth International Workshop on Verified Storage and Destruction of Nuclear Warheads,* Washington, DC, 26–27 February 1992; William G. Sutcliffe, *Warheads and Fissile Materials: Declarations and Counting,* Report UCRL-JC-108073, CTS-27-91, Livermore, 5 August 1991. Chinese examples are contained in the volume of the Institute of Applied Physics and Computational Mathematics (IAPCM), Program for Science and National Security Studies (Arms Control Collected Works), Beijing, 1995.

[8] Wolfgang Rosenstock *et al.*, Entwicklung und Untersuchung von transportablen Meßsystemen zur Verifikation von Kernwaffen (Development and investigation of transportable measuring systems for the verification of nuclear weapons), INT-Bericht no. 162, Euskirchen, December 1995; Wolfgang Rosenstock *et al.*, Aufbau einer transportablen Detektoranordnung zur Verifikation von A-Waffen (Construction of a transportable detector device for the verification of nuclear weapons), INT-Bericht no. 169, Euskirchen, April 1997.

[9] Tian Dongfeng, Xie Dong and Liu Gongliang, High Energy Gamma-Ray 'Fingerprint' – A Feasible Approach to Verify Nuclear Warhead, in IAPCM.

[10] There are various, some very cheap, methods of sealing. Many are being applied and further developed by the IAEA and EURATOM. One example is a forgery-proof method, in which characteristic optical samples are created by means of fibre optic bundles. IAEA, *Safeguards Techniques and Equipment,* International Nuclear Verification Series, no. 1, Vienna, 1995.

[11] Nikolai Sokov, 'Tactical Nuclear Weapons Elimination: Next Stop for Arms Control', *The Nonproliferation Review,* vol. 4, no.2, 1997.

[12] Klaus Kinkel, 'German 10-point initiative for nuclear nonproliferation', Bonn, Germany, 15 December 1993. For the significance of this proposal and the reaction of the NWS, see Harald Müller, 'The Nuclear Weapons Register – A Good Idea Whose Time Has Come', *PRIF Reports,* no. 51, June 1998.

[13] Jozef Goldblat, 'Nuclear-Weapon-Free Zones: A History and Assessment', *The Nonproliferation Review*, spring–summer 1997, p. 18; see also chapter by David Fischer in this volume.

[14] For details on safeguards, see chapter by David Fischer in this volume.

[15] An example is President George Bush's Middle East Arms Control Initiative of 29 May 1991. See Zachary Davis, 'A Nuclear-Weapons-Free Zone in the Middle East: Background and Issues', *CRS Issue Brief,* 13 March 1992. See also UN General Assembly: Establishment of a Nuclear-Weapon-Free Zone in the Region of the Middle East, A/45/435, 10 October 1990.

[16] See chapter by David Fischer in this volume.

[17] Annette Schaper, The Case for Universal Full Scope Safeguards on Nuclear Material, *The Nonproliferation Review*, vol. 5, no. 2, winter 1998, p. 69.

[18] See Annette Schaper, 'A Treaty on the Cutoff of Fissile Material for Nuclear Weapons – What to Cover? How to Verify?' *PRIF Reports,* no. 48, July 1997.

[19] Press Statement on the Trilateral Initiative, *IAEA Press Release,* PR 97/26, 30 September 1997; Thomas Shea, 'Verification of Weapon-Origin Fissile Material in the Russian Federation &United States', *IAEA Bulletin,* vol. 41, no. 4, 1999, p. 36.

[20] Bukharin and Handler.

[21] Shea.

[22] Moscow Nuclear Safety and Security Summit Declaration, 20 April 1996. The P8 countries are Canada, France, Germany, Italy, Japan, Russia, UK and US.

[23] Strategic Defence Review, presented to UK Parliament by the Secretary of State for Defence by Command of Her Majesty, London, July 1998. See www.mod.uk.