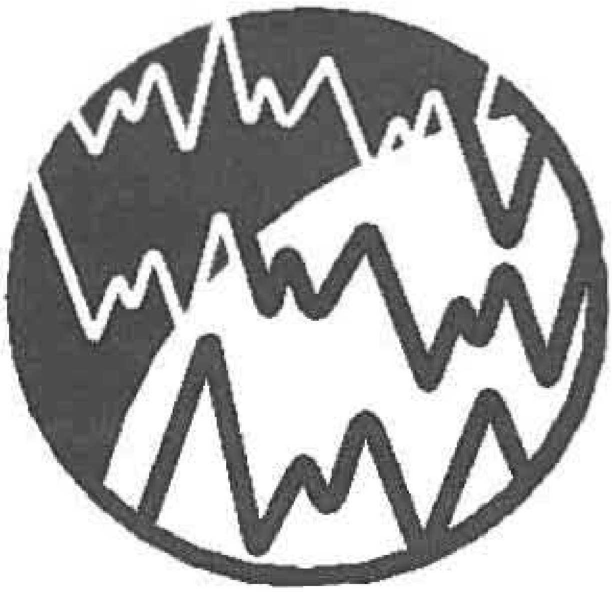
Verifying the Transition from Low Levels of Nuclear Weapons to a Nuclear Weapon-Free World



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VERTIC research report No 2

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VERTIC is an independent, non-profit making, non-governmental organisation. Its mission is to promote effective and efficient verification as a means of ensuring confidence in the implementation of treaties or other agreements that have international or national security implications.

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Preface

In 1996 VERTIC launched a project funded by the W. Alton Jones Foundation and the Ploughshares Fund on Verification of the Transition to a Nuclear Weapon-Free World and Sustaining the Verification Regime for an Indefinite Period.

The aim of the project is to investigate the verification challenges facing the transition to complete nuclear disarmament and how a verification regime might be sustained once zero nuclear weapons had been achieved. Verification is clearly the key to achieving nuclear disarmament, since without it the risk of 'breakout'—the illicit retention or production of nuclear weapons—would be high and the inclination to actually abolish nuclear weapons low. Verification of nuclear disarmament therefore needs to be highly intrusive and thorough, allowing for as little margin of error as possible. Given the extreme sensitivity of the nuclear weapon states about their security requirements, especially regarding their nuclear capability, this will be enormously difficult.

Many questions are pertinent: how should a verification regime be structured so that there is a high degree of confidence that no country or organisation could be hiding or manufacturing a stockpile? what technologies and techniques are most appropriate? how can one build on the precedents set by other nuclear agreements such as the Intermediate Nuclear Forces (INF) Agreement and START I and II and non-nuclear agreements such as the Chemical Weapons Convention and the Biological Weapons Convention? how is the verification regime to be staged to match the gradual dismantling and destruction of nuclear arsenals? what does one do about nuclear materials, nuclear laboratories and nuclear knowledge? how is the verification regime to be implemented so that it builds trust and confidence? how are the de facto nuclear weapon states to be brought into the process and will the same verification provisions apply to them as to the declared nuclear weapon states? are nuclear and non-nuclear confidence-building measures required to supplement the verification regime? how can the regime cope with breakout should it occur?

Not only does the verification of nuclear disarmament have to be effective and efficient during the process of getting to a nuclear weapon-free world, it is also vital that there is confidence in the verification regime's ability to survive indefinitely.

Questions here include: for how long do we need an intrusive verification regime? 50 years? 100 years? can nuclear weapons be re-manufactured by a former nuclear weapon state within a short time-frame or would they have to be essentially re-invented? what happens if the international situation seriously worsens? how do we implement the regime so that enthusiasm, expertise and funding are maintained? should the strictness of the regime be eased over time as a nuclear weapon-free world becomes the norm?

The research product of the VERTIC's 'Getting to Zero' project comprises four reports dealing with:

1) verification of the transition to low levels of nuclear weapons, covering the period in which the nuclear weapon states would be expected to cut their nuclear warheads to below 1000 each;
2) verification of the transition to a nuclear weapon-free world, covering the period when complete nuclear disarmament is achieved and detailing the type of treaty and accompanying verification arrangements likely to be required;
3) management and verification of virtual nuclear deterrence, whereby residual nuclear capabilities (such as skilled personnel, fissionable materials and general industrial capacity) would give some states, especially former nuclear weapon states, the edge in any attempt to reconstitute nuclear weapons, thereby giving them a form of nuclear deterrence; and
4) how to sustain the verification system for a nuclear weapon-free world into the indefinite future.

This report, by Tom Milne and Henrietta Wilson, is the second in the series.

Trevor Findlay
Series Editor
July 1999

Executive Summary

- The process of verifying the complete elimination of nuclear warheads in national stockpiles can be divided, conceptually, into four stages:first, comprehensive declarations of warhead and material inventories, as a base-line from which verified disarmament can proceed; second, the transfer of all nuclear weapons and weapons-grade fissile material into bonded store; third, demilitarisation measures, such as to render warheads unusable without disassembly and refabrication; fourth, dismantlement of warheads and disposition of fissile material.

- Many of the technologies and techniques needed for verifying the elimination of nuclear warheads have been worked out at a general level, largely in US studies. While it is essential that these techniques are refined and improved, what is most important now, if disarmament is to proceed expeditiously, is for each of the nuclear weapon states (NWS) themselves to study the central verification problems and requirements in order to identify particular techniques and approaches that meet their needs.

- As yet there is no system of integrated data exchange and verification that any of the NWS is willing to endorse.

- Each of the NWS should give detailed consideration to the logistics of dismantling the warheads in their respective stockpiles, including, for example, the practicalities of accommodating international verification at their potential dismantlement facilities.

- Each of the NWS might usefully review exactly which details of warhead design and construction have to remain secret in the course of the disarmament process, in the first place from one another, and second from the IAEA or any other international body that might be involved in international disarmament arrangements.

- Introducing transparency and verification into national nuclear weapons programmes might have a significant financial cost. Research and ingenuity might reduce this cost, however, and early investments in these fields, with sharing of results, would be very useful.

Detecting Cheating in a Nuclear Weapon-Free World

• By far the hardest verification problem facing nuclear disarmament is the of illicit acquisition or retention of nuclear weapons. This challenge would benefit from further study by each of the nuclear weapon states and as many other nations as are willing to devote resources to supporting nuclear disarmament.

• As is the case for all disarmament agreements, an industrialised country could, in theory, circumvent verification measures included in a nuclear weapons convention. But a verification regime should reduce the uncertainties in disarmament, and demonstrate an open and co-operative approach to creating a nuclear weapon-free world.

• Verification is just one of many possible interlocking measures in an international disarmament treaty, and should not be seen as the single most important. While verification regimes have an important role to play in encouraging the participation of states in international disarmament treaties, and in ensuring that these treaties are effective, they are only one part of a wider disarmament process.

Time-trends

• Since nuclear weapons might be eliminated over decades, it is relevant to consider the main respects in which the possibilities for verifying nuclear disarmament could change on such a timescale. Two important trends, in this respect, are those towards greater openness in the world, and towards improving technological verification capabilities.

• Greater openness at nuclear weapons facilities is of particular importance in building international confidence in disarmament. Whenever possible, national research programmes on verification and other aspects of arms control, non-proliferation and disarmament, should involve international collaboration, since this could be a primary means of increasing openness, as well as of perfecting verification techniques.

- Openness at nuclear weapons establishments, including regular interactions between nuclear weapons scientists from different countries, should promote societal verification.

- Technological verification capabilities can be expected to improve as a consequence of general technological advance, and based on the work of dedicated verification R&D programmes at national nuclear weapons laboratories and elsewhere.

- Currently, research into verifying nuclear disarmament is dominated to an unhealthy extent by the US, because of the paucity of effort elsewhere. Additional funds for R&D in the US on verification and arms control could be spent wisely, but the main scope for increased R&D lies in other countries.

- It is desirable that there be a wide range of national nuclear verification R&D programmes. These would have the three-fold purpose of carrying out new research, including making practical preparations for disarmament; providing a general education to national scientists and officials in the field of arms control and disarmament, crucial for future disarmament negotiations; and building international confidence in verification techniques.

Glossary

AWE	Atomic Weapons Establishment (Aldermaston)
ACDA	Arms Control and Disarmament Agency (US)
BNFL	British Nuclear Fuels plc
BWC	Biological Weapons Convention
CFE	Conventional Forces in Europe (Treaty)
CTBT	Comprehensive Nuclear-Test-Ban Treaty
CWC	Chemical Weapons Convention
DOD	Department of Defense (US)
DOE	Department of Energy (US)
DTI	Department of Trade and Industry (UK)
EURATOM	European Atomic Energy Community
ENDC	Eighteen-Nation Disarmament Committee
FCO	Foreign Commonwealth Office
FMD	fissile materials disposition
FSU	former Soviet Union
GAO	General Accounting Office (US)
HEU	highly-enriched uranium
IAEA	International Atomic Energy Agency
ICBM	Inter-continental Ballistic Missile
IDC	International Data Centre (supporting the CTBT)
IMS	International Monitoring System (of the CTBT)
INF	Intermediate-range Nuclear Forces (Treaty)
IPP	Initiatives for Proliferation Prevention
JOWOG	Joint Working Group
JVE	Joint Verification Experiment
LEU	low-enriched uranium
MOD	Ministry of Defence (UK)
MPC&A	material protection, control and accounting
NDC	National Data Centre (supporting the CTBT)
NGO	non-governmental organisation
NIS	Non-Proliferation and International Security Division, Los Alamos National Laboratory (US)

NPT	Non-Proliferation Treaty
NTM	national technical means
NWFW	nuclear weapon-free world
NWFZ	nuclear weapon-free zone
OPCW	Organization for the Prohibition of Chemical Weapons
OSI	on site inspection
OSIA	On Site Inspection Agency
OTA	Office of Technology Assessment
PPAC	Proliferation Prevention and Arms Control Program, Lawrence Livermore National Laboratory (US)
RDT&E	research, development, testing and evaluation
R&D	research and development
START	Strategic Arms Reduction Talks/Treaty
U-235	Uranium 235
UKAEA	United Kingdom Atomic Energy Agency
UNSCOM	UN Special Commission (for Iraq)
VERTIC	Verification Research, Training and Information Centre

1. Introduction

In this report we discuss the verification requirements for moving from low levels of nuclear weapons, defined as being in the hundreds per nuclear weapon state, to a nuclear weapon-free world (NWFW). Since the United States and Russia currently have more than 10,000 warheads each, deployed, stockpiled or awaiting dismantlement,[1] the report is concerned with a stage of disarmament that can occur only at some unspecified time in the future. The discussion is, therefore, in part hypothetical and imaginative.

It is beyond the scope of the report to discuss the prospects for a reduction in the superpower arsenals to low levels. We note only that economic conditions in Russia mean that its nuclear arsenal is shrinking faster than mandated by the Strategic Arms Reduction Talks (START) process; without an economic upturn, it has been estimated that in as little as 10-15 years the Russian arsenal will have been reduced to an order of magnitude comparable to those of the minor nuclear weapon states, that is to say, a few hundred warheads.[2] In terms of the logic of deterrence, the US has the opportunity to reduce its nuclear arsenal at a comparable rate.

While it is possible to imagine developments that might drastically speed up progress towards zero, few expect that a nuclear weapon-free world will be created in less than 20 years. Every nuclear warhead in existence could be dismantled over several years (or demilitarised in just a few months) were sufficient resources allocated to this purpose,[3] but enduring reservations held by most policy-makers and exhibited by public opinion in the nuclear weapon states mean that progress is likely to remain cautious and incremental.

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[1] For exact numbers see Thomas B. Cochran, Robert S. Norris and Christopher E. Paine, 'Progress in Nuclear Weapons Reductions' in Joseph Rotblat (ed.), *Nuclear Weapons: The Road to Zero*, Westview Press, Boulder, Co., 1998, pp. 157-189. Regular updates can be found in the NRDC Notebook in the *Bulletin of the Atomic Scientists*.

[2] Bruce Blair, 'Russia's Nuclear Collapse: The Case for a Mutual Stand-Down' in Frank Blackaby and Tom Milne (eds), *A Nuclear-Weapon-Free World: Steps Along the Way*, Macmillan, London, forthcoming. Russia's Defence Minister Igor Sergeyev has stated publicly that, for economic reasons, Russia is likely to have no more than 500 deployed strategic warheads by 2012: reported in *Jump-START: Retaking the Initiative to Reduce Post-Cold War Nuclear Dangers*, Committee on Nuclear Policy, The Henry L. Stimson Center, Washington DC, February 1999.

[3] For example, the rate of dismantlement of US warheads over the past several years (ca. 1,500 a year) is constrained by the fact that the management at the Pantex facility at Amarillo, Texas, where US weapons are assembled, maintained and dismantled, did not think it prudent to expand the work force employed on this task. See Richard L. Garwin, 'Verification and Transparency: New Technical Possibilities' in Blackaby and Milne.

If two or more decades is the timescale in which nuclear weapons might be eliminated, it is relevant to consider the main respects in which the possibilities for verifying nuclear disarmament could alter over such a period. This is one of the main themes of this report. At the same time, however, the report assumes that the world will continue to function in much the same way as today, politically and legally, with the continued existence of nation states and a discrete but small number of nuclear weapon states. Linking nuclear disarmament to general and complete disarmament, for example, or to the establishment of world government, reduces the goal of a nuclear weapon-free world to little more than a token objective and makes discussion of verification requirements redundant.

The Role of Verification in a Nuclear Weapons Convention

If and when states decide to relinquish their last remaining nuclear weapons, it is likely they will do so in a legal framework—an international convention that codifies commitments and responsibilities. The exact content and form of a future nuclear weapons convention can only be fixed by negotiation, although there have been attempts to sketch out a model.[4] In this report we are concerned with the role of verification in such a convention.

Verification is the system whereby parties to an arms control and disarmament agreement can assure themselves about the compliance of others and demonstrate their own compliance. It is a means of building confidence in a disarmament regime and is generally complemented by other safeguards such as protection and enforcement measures.

Mechanisms that build confidence in treaty implementation and provide participating states with assurance that the risks accompanying disarmament are minimised are a common feature of international disarmament agreements. First, these measures encourage membership of the agreements. Before eliminating their nuclear arsenals, nuclear weapon states will need to be confident that their security will be served by the creation of a nuclear weapon-free world. They will seek assurance that treaty commitments are being met by all, including, for example, that each state is disarming as agreed, that the risk of states illicitly acquiring

[4] For example, a model convention drafted by non-governmental organisations (NGOs) was submitted to the UN by Costa Rica in November 1997 (UN document A/C.1/52/7).

weapons is minimised, and that if violations should occur, their effects will also be minimised. Building confidence in disarmament regimes can also be a useful end in itself, leading to increasing trust between states and stimulating subsequent disarmament. This was an outcome, for instance, of the 1986 Stockholm Accord, which was a prerequisite for the 1990 Conventional Forces in Europe (CFE) Treaty.

Confidence in disarmament derives from a variety of interdependent measures incorporated into treaties. For example, technologies that can detect violations force would-be violators to go to greater lengths to hide their activities, making cheating on an agreement more costly, more complicated, and perhaps more likely to be discovered. Detection techniques can also provide assurance that cheating occur, it will be discovered early enough that appropriate enforcement measures can be set in motion. Such enforcement might comprise commitments to respond to any violations with collective punitive action. A treaty might commit member states to apply economic sanctions, for example, against a state caught rearming, or to take collective military action in response to the use of an outlawed weapon.

Verification is thus one of the methods by which states can be assured of the desirability and feasibility of a disarmament regime. Indeed, it has become a prominent means of providing such assurance. This is particularly true in the case of nuclear disarmament and non-proliferation since many of the relevant means of verification are well understood and known to be effective. It is also significant that verifying nuclear disarmament is not impeded by the presence of a pervasive civilian industry, as is the case for chemical disarmament, where verification is complicated by the ubiquitous presence of precursors of chemical warfare agents which have civil applications.

It is sometimes argued, however, that the viability of a prospective or existing treaty is equivalent to its verifiability—that unless treaty compliance can be verified with complete certainty the treaty is worthless. This is too narrow a view. Even though many aspects of verifying nuclear disarmament are likely to be effective, uncertainties in verifying overall compliance with a nuclear weapons convention are inevitable, due to limitations of technologies and practical constraints imposed by treaty provisions. Treaty verification is not solely a technical enterprise that can be solved by the use of ever more sophisticated technologies. Rather, it comprises many tasks and techniques, from processing completed declaration forms, to analysis of chemical samples, to inspections of military and scientific facilities. Like all components of an international disarmament treaty, a verification regime has to be negotiated and reflects compromises between states.

Verification is thus just one of many possible interlocking measures in an international treaty and should not be seen as the most important. While verification regimes have an important role to play in encouraging the participation of states in international disarmament treaties and in ensuring that these treaties are effective, they are not a 'magic bullet', and must be seen as one part of a wider disarmament process.

Getting to Low Levels of Nuclear Weapons

The prospects for the total elimination of nuclear weapons some years hence will be affected by the experience with disarming between now and then. It is conceivable that the process of reducing stockpiles from current to low levels could build confidence in the disarmament regime, demonstrating that nuclear disarmament can be a peaceful and cost-effective means of maintaining national and international security and that verification is a worthwhile exercise. But equally, reductions to low levels might provoke a 'backlash' against disarmament, reinforcing doubts about the desirability and feasibility of eliminating nuclear weapons. This might occur if, for example, agreements are not effectively implemented, they cost too much, or the verification system fails to detect a treaty violation.[5]

In particular, much might hinge on how the process of going from current to low levels of warheads is verified. In the first paper of this series,[6] Patricia Lewis outlines a possible disarmament scheme for reducing nuclear weapons stockpiles to low levels. She shows that establishing a verification regime at an early stage is important in preparing for further reductions to zero. In the period of reductions to

[5] The 1972 Biological and Toxin Weapons Convention (BWC) is widely perceived to be a weak treaty because of its lack of verification and compliance measures. This perception was somewhat validated when it was discovered that the Soviet Union, a treaty depositary, had continued to maintain a biological warfare programme, testing and producing BW agents after entry into force of the treaty. The Russian government formally admitted this in 1993 when announcing that all such programmes had been closed down. Yet the discovery of this violation did not result in the breakdown of the treaty regime. Rather, negotiation of a protocol to strengthen the treaty is now underway, and is to include verification mechanisms.

low levels, she argues, it will be necessary to 'build a databank of knowledge on the nuclear weapon programmes of each nuclear weapon state and, eventually, of the de facto nuclear weapon states'.[7]

In Lewis' approach, disarming from current to low levels should integrate verified disarmament with transparency and confidence-building, including data exchanges verified by on-site inspections. The result would be that 'after several years of verifying the transition to low levels of nuclear weapons, a pattern of knowledge would be assembled, increasing confidence in the process'.[8] To give just one example, by the time that low levels of nuclear weapons are achieved, international safeguards on the nuclear fuel cycle might have been extended to cover all relevant facilities in all states. There might also be much greater openness among the nuclear weapon states about the size, form and location of remaining stockpiles of fissile material in military programmes.

Nuclear reduction agreements to date, notably the Intermediate-range Nuclear Forces (INF) and Strategic Arms Reduction Talks (START I and II) agreements, have been concerned only with warhead delivery vehicles. As nuclear arsenals are reduced to low levels (the stage of the disarmament process with which we are concerned), arrangements for verifying the elimination of the warheads themselves are likely to be introduced into disarmament agreements. The first step could be to monitor the accumulation of warhead pits at a storage facility to await final disposition. While not necessarily providing assurance that a particular type or class of warhead was being dismantled, this would at least provide confidence that the total stockpile was being reduced in size. At some point, though, more rigorous verification will be required. Considerable research on verifying the elimination of nuclear warheads has already been done, mostly in the US.[9] In order not to

[6] Patricia M. Lewis. *Laying the Foundations for Getting to Zero: Verifying the Transition to Low Levels of Nuclear Weapons*, *VERTIC Research Report* no. 1, VERTIC, London, 1998.
[7] Lewis, p. 10.
[8] Lewis, p. 3.
[9] In addition to several studies by various US Department of Energy national laboratories, there was a 1991 report *Verifying the Dismantlement of Nuclear Warheads* by the Federation of American Scientists, and a 1993 report, *Verification of Dismantlement of Nuclear Warheads and Controls on Nuclear Materials*, by the JASON group (JASON/MITRE, JSR-92-331, January 1993). All these studies are summarised in a detailed 1997 analysis by the Office of Arms Control and Nonproliferation in the Department of Energy. See Andrew J. Bieniawski, *Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement*, Office of Arms Control and Nonproliferation, Department of Energy, Washington DC, 19 May, 1997. Independent analyses of the issues include Theodore B. Taylor and Lev P. Feoktistov 'Verified Elimination of Nuclear Warheads and Disposition of Contained Nuclear Materials' in Francesco Calogero, Marvin L. Goldberger and Sergei P.

recapitulate the thorough analyses of verification techniques in the open literature, we attempt in this report only to outline, at a conceptual level, the central issues that arise and to point to areas where further work is needed.

For this purpose, the process of verifying the elimination of nuclear warheads can be divided into four parts. First, comprehensive declarations of warhead and fissile material inventories; second, consolidation of warheads and fissile material in 'bonded store'; third, demilitarisation measures; and fourth, dismantlement of warheads and secure disposition of the contained fissile material. While such a scheme represents a logical approach to disarmament, the four stages need not, of course, be strictly sequential. Indeed it is likely, for example, that the US and Russia will establish bilateral disarmament arrangements before multilateral agreement can be achieved.

Verifying the elimination of declared nuclear arsenals is unquestionably a substantial and complex enterprise. It is, nonetheless, the easy part of the overall verification task. A further role for verification, discussed in the final section of this report, is the detection of cheating through the clandestine acquisition or retention of nuclear weapons. The small size of modern nuclear warheads, and the lack of readily observable characteristics makes detection of the 'bomb in the basement' by far the most problematic verification issue facing nuclear disarmament. It is a concern often cited by those most sceptical of moving towards an NWFW any time soon.

Kapitsa (eds), *Verification: Monitoring Disarmament*, Westview Press, Boulder, Co., 1991, pp. 45-66; and Theodore Taylor, 'Technological Problems of Verification' in Joseph Rotblat, Jack Steinberger and Bhalchandra Udgaonkar (eds), *A Nuclear-Weapon-Free World: Desirable? Feasible?*, Westview Press, Boulder Co., 1993, pp. 68-82.

2. Verifying the Elimination of Nuclear Arsenals

A Comprehensive Data Exchange

In the process of moving from current to low levels of nuclear weapons, the nuclear weapon states should have agreed on an integrated data exchange, including details like type, serial number and operational status of every nuclear warhead, and all relevant aspects of their military nuclear programmes. This declaration, continualy updated, would be the starting point for a comprehensive approach to verifying nuclear disarmament to zero.

As yet there is no system of integrated data exchange and verification that any of the nuclear weapon states is willing to endorse. In June 1995 the US proposed a detailed data exchange with Russia, covering existing inventories of warheads and fissile materials, dismantlement of nuclear weapons since 1980 and production of fissile material since 1970. But this was rejected by Russia as too 'comprehensive' and inconsistent with a 'step by step' approach to transparency.[10]

The only existing transparency surrounding warhead and fissile material inventories has come from partial declarations unilaterally made by the US (which has revealed the most among the nuclear weapon states about both warheads and fissile materials), Russia (which has done little more than declare quantities of plutonium and highly-enriched uranium surplus to military requirements) and the UK (which has promised greater transparency about fissile material stocks and is consulting with academic bodies and non-governmental organisations (NGOs) about declassification of information on its nuclear weapons programme).[11]

Such partial transparency could be the start of a series of incremental measures to build confidence, but as yet it does little to satisfy formal confidence-building and disarmament objectives.[12] The sooner that comprehensive data exchanges are made,

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10 Bieniawski, p. 23.
11 For a discussion of the current state of transparency measures, see Thomas B. Cochran, 'Transparency Associated with the Process of Eliminating Nuclear Warheads' in Blackaby and Milne.
12 *Ibid.*

and either the nuclear weapon states or an international body can begin to monitor all nuclear warheads and material, the better.

Introducing at an early stage reciprocal inspections among the nuclear weapon states (or inspections by an international body) of warhead storage facilities, production plants and research and development (R&D) sites, will create greater confidence as arsenals are being reduced to low levels and when they eventually are reduced to zero. There is less incentive to cheat on a disarmament agreement while numbers of warheads are relatively high (as is the case in the US and Russia today), if only because of the period that would necessarily elapse before the cheating could have any possible 'value' it would be longer than most governments could expect to survive. And, as Lewis argues, in time a 'pattern of knowledge' would be established, providing further reassurance.

It is likely that, initially, any such inspections would be performed mutually among the nuclear weapon states, as for example in the START process, rather than by an international organisation such as the International Atomic Energy Agency (IAEA). At some stage in the disarmament process, however, inspectors from non-nuclear weapon states should become involved, to provide international scrutiny. A balance has to be struck between creating international confidence in disarmament, and putting unnecessary impediments in the way of progress. There are obvious difficulties, for instance, in international inspection of the dismantlement of warheads. The nuclear weapon states would not want to divulge certain information on nuclear weapon design and indeed are obliged not to do so by the Nuclear Non-Proliferation Treaty (NPT) to which they are all party. But at the same time, and as discussed at later points in this report, there are steps that could be taken for example the construction of dedicated dismantlement facilities, for example, designed to accommodate international verification—that might make it possible for the nuclear weapon states to provide sufficient transparency to international bodies. In planning and preparing for nuclear disarmament, each of the nuclear weapon states might usefully review, exactly which details of warhead design and construction *have* to remain secret, in the first place from other nuclear weapon states, and second from the IAEA, a body which has much experience of working with and protecting sensitive information.

A situation in which all nuclear weapons are moved from deployment in the field or from reserve stockpiles to 'bonded store' might be achieved according to an explicit plan and timetable, or more likely as a result of a series of steps, some bilateral, some multilateral, which gradually build confidence and increase openness in the disarmament process.

Bonded Store

The starting point for consideration of the final step to zero can be taken as a situation in which all remaining warheads and weapons-grade fissile material are held in 'bonded store'. That is to say, each nation in possession of nuclear warheads and fissile material produced outside safeguards has made available a detailed inventory of its remaining warheads and materials. These warheads and materials are stored in sealed containers, monitored either by permanent representatives appointed according to an international agreement or using a range of sensors to transmit data directly via satellite link to an external site.[13] Inspectors will have access to the storage sites to audit the inventories and verify that the objects and materials held are nuclear warheads and weapons-grade material as declared.

Research is underway on warhead authentication techniques, based on measurements of radiation emissions and other characteristic signatures. But it is expected that authentication of nuclear warheads will be one of the most problematic aspects of verifying the disarmament process. The requirement is to authenticate an object inside a sealed vessel, declared to be a warhead, without revealing sensitive design information.[14] Examples of objects that might be substituted for real warheads include warheads in which natural or depleted uranium has been substituted for plutonium and highly-enriched uranium (HEU); objects closely resembling real warheads but fabricated to less demanding

13 There is, for instance, a collaborative project on storage monitoring technology between Sandia National Laboratories in the US and the Russian nuclear weapons design centre Arzamas-16. Both establishments house nuclear materials storage containers (for the time being not containing nuclear material) monitored by a range of sensors (temperature, motion, radiation, fibre optic seals, cameras etc.). The data from the sensors is transmitted directly to the Internet. This experiment is due to be extended to include joint monitoring of storage magazines, and ultimately whole facilities, and to include actual nuclear materials. A further step will be to integrate storage monitoring with the physical protection and material accounting systems at the sites.

14 If the inspector is from another nuclear weapon state, a concern might be shielding against radiation, for example. And although the concern about design information, from the point of view of system vulnerability, might be reduced if all the warheads of a particular type are being eliminated, there would continue to be concern about design features common to different warheads. If the inspector is from a non-nuclear-weapon state, more basic design features might have to be protected.

specifications; or genuine warheads containing much less fissile material than the warheads supposedly being eliminated.[15] Likewise, but more straightforwardly, techniques are being developed for confirming that weapons-grade plutonium, for example, is contained inside a sealed canister, again without disclosing classified information.

If warhead authentication proves difficult, the substitution of fake warheads for real warheads can be deterred using 'fingerprinting' techniques. These can be used to compare the contents of canisters purportedly containing warheads of the same type. A warhead 'fingerprint', difficult to replicate, can be formed from measurements of the warhead's weight, radiation emissions and other characteristics. It is used to ensure that successive items entering the dismantling facility are identical. Classified data comprising the warhead fingerprint can be protected by a system that reveals only whether a given warhead does or does not differ significantly from a standard template. In this way, a nation that attempts to withhold warheads from the disarmament process is forced to substitute fakes for *all* warheads of the type withheld. This makes the deception much more complicated than replacing a handful of warheads for a secret nuclear force.[16]

After warhead authentication, chain-of-custody procedures utilising tamper-indicating tags and seals, remote monitoring devices, and direct observation, can provide confidence that the warhead has been dismantled and the weapons-grade materials placed under international safeguards.

If nuclear weapons are still deployed when the decision is taken to go to zero, arrangements will need to be made for their secure transportation to the warhead storage or dismantlement facility. Chain-of-custody procedures are already used by the nuclear weapon states for the routine transportation of warheads, but these would have to be opened to verification. Richard Garwin describes, for example, how a fibre optic net could be placed over each weapon and a tag attached that would be invalidated if the net were broken.[17]

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[15] Theodore B. Taylor and Lev P. Feoktistov, 'Verified Elimination of Nuclear Warheads and Disposition of Contained Nuclear Materials,' in Calogero, Goldberger and Kapitza.

[16] For a discussion of warhead fingerprinting and of deterrents to substitution of fake warheads see Taylor and Feoktistov.

[17] See Garwin. He proposes use of a net for nuclear weapons, rather than the sort of encasement suitable for transporting or storing warheads or fissile materials, because nuclear weapons are relatively large and it could be awkward and costly to encase the weapons for transportation.

A unique tag should be affixed to each of the warheads and containers of fissile material held in bonded store. If an untagged warhead canister or container of fissile material then discovered in a subsequent inspection, this would be direct evidence of cheating on the disarmament agreement. Tagging also allows an inspector to verify the authenticity of a *particular* warhead or container of fissile material selected from the declared inventory at random. In this way high confidence of detecting cheating can be obtained by statistical sampling techniques (in place of exhaustive checks), simplifying the verification procedure.[18]

Demilitarisation

As nuclear arsenals are reduced, concerns are likely to be raised about the potential for breakout— in which a nation openly or covertly withdraws from a disarmament agreement and reconstitutes a military nuclear force. Whether breakout poses a serious threat is controversial and widely discussed.[19] If breakout is perceived to be a danger, technical measures that provide reassurance should be considered.

One means of reassurance would be to eliminate, under verification, all ballistic missiles capable of carrying nuclear weapons. Although the absence of nuclear warheads is the basic yardstick for verifying a nuclear weapon-free world (because nuclear warheads can be delivered in many ways other than by missile), the elimination of strategic delivery vehicles would remove an important part of a nation's strategic nuclear capability.[20]

The INF and START agreements provide proven models for the verified destruction of missiles which could be replicated in a multilateral treaty. Although

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18 Steve Fetter, *Verifying Nuclear Disarmament. Occasional Paper* no. 29. The Henry L. Stimson Center. Washington DC, 1996, p. 11.

19 See. for example, Marvin Miller and Jack Ruina. 'The Breakout Problem,' in Rotblat, Steinberger and Udgaonkar , pp. 83-102; Michael MccGwire, 'Eliminate or Marginalize? Nuclear Weapons in U.S. Foreign Policy,' *The Brookings Review*, Spring 1995; Andrew Mack. 'Nuclear Breakout: Risks and Possible Responses,' *Canberra Commission on the Elimination of Nuclear Weapons: Background Papers*, Department of Foreign Affairs and Trade. Canberra, 1996, pp. 291-315; Tom Milne and Joseph Rotblat. 'Breakout from a Nuclear Weapons Convention' in Joseph Rotblat (ed.). *Nuclear Weapons: The Road to Zero*, Westview Press, Boulder Co., 1998, pp. 145-154.

20 Note, however, the argument that new nuclear nations would in most cases be foolish to build a few ICBMs with nuclear weapons to threaten one of the nuclear weapon states. It would be easier, more effective and potentially more damaging to plan to detonate nuclear weapons in harbours or to use short-range cruise missiles or ballistic missiles from civilian cargo ships offshore.

INF and START are bilateral US-Russian arrangements, the elimination of nuclear delivery vehicles has been studied by other nations.[21]

A second method of demilitarisation would be to make an irreversible physical alteration to the warheads held in bonded store, rendering the warhead unusable without disassembly and refabrication. US warheads can be demilitarised quickly, cheaply, and in a manner open to verification.[22] The same might be true for warheads produced by the other nuclear weapon states.

Last, although discussed here in relation to breakout, demilitarisation of nuclear weapons is of course desirable at any stage in a disarmament process, since it effectively removes the possibility of accidental or unauthorised use.

Dismantlement of Warheads and Disposition of Fissile Material

After warheads have been authenticated, they can remain in bonded store in containers protected with tamper-indicating seals until they are transported, employing chain-of-custody procedures, to the dismantlement facility.

In the US, where techniques for verifying warhead dismantlement have been studied in some depth, the term 'transparency' is often used for the monitoring of warhead dismantlement, rather than 'verification.'[23] This is because of the widespread concern that it would be impossible to 'verify' that an object being dismantled is a warhead without revealing more about design features than would be acceptable from a security standpoint, or legal under current national regulations.[24] The expectation is that, over time, mutual transparency will provide

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21 For an early British analysis, see British Paper Submitted to the Eighteen-Nation Disarmament Committee: Preliminary Study of Problems Connected with the Elimination of Rockets as Nuclear Delivery Vehicles, August 1, 1962, ENDC document ENDC/53; and British Paper Submitted to the Eighteen-Nation Disarmament Committee: Preliminary Study of Problems Connected with the Verification of the Destruction of Certain Nuclear Delivery Vehicles. August 1, 1962. ENDC document ENDC/54.

22 Garwin.

23 The DoE report *Transparency and Verification Options* defines transparency as measures that provide confidence that a declared activity is taking place, and verification as measures that confirm that a declared activity is taking place.

24 Regulations such as these are not immutable. It was only in 1994 that the US established a legal mechanism for exchanging classified information with other nations for arms control and non-proliferation purposes.

sufficient confidence for dismantlement agreements to work without rigorous verification.

It is conceptually simple to consider a dismantling facility as having one entrance and one exit. The passage of warheads entering the facility should be monitored and correlated with warhead pits, reformed into shapes that have no security classification, passing through the exit. The pits would then be placed under international safeguards and taken to storage facilities to await final disposition.[25] The dismantlement facility should be enclosed within patrolled boundaries, equipped with sensors and other technical safeguards. All objects leaving the facility should be inspected (with radiation detectors, for example) to prevent warheads or materials being smuggled out.

Citizens of the country that owns the warheads should dismantle them. The dismantlement process need not be observed, since the facility could be inspected periodically (in theory after each warhead is dismantled) to ensure that neither warheads nor materials were being illegally accumulated. To give additional confidence, chain-of-custody procedures could be employed within sections of the dismantling areas. Either remote observation of the dismantling process via video camera or direct observation by disarmament inspectors, could be arranged after appropriate shielding was in place.[26]

The need for intrusive verification of the dismantling process could be considerably reduced if it proves possible to use radiation 'signatures' to correlate warheads entering the dismantlement facility with warhead components exiting. This technique is currently being investigated by US laboratories. The main uncertainties

25 Options for the disposition of fissile materials recovered from weapons have been studied in depth in the US. see for example *Management and Disposition of Excess Weapons Plutonium*, Committee on International Security and Arms Control. National Academy of Sciences, National Academy Press. Washington DC 1994. The appropriate security standard for weapons plutonium is the 'spent fuel standard,' which is that the plutonium should be no more attractive for re-use in weapons than the fissile material contained in spent nuclear fuel. Similarly, HEU should be diluted to what is characterised as Low-Enriched Uranium (LEU) by the IAEA—19.9% Uranium-235 or less. There would be little point in striving to make surplus military fissile material less suitable for reintroduction into weapons than materials in the civilian fuel cycle.) For surplus plutonium, the US has decided to develop two techniques for disposition in parallel: 1) converting the plutonium into mixed oxide fuel to be burned in power reactors: and 2) mixing the plutonium with highly radioactive waste and 'immobilising' it in glass. It is straightforward to dilute HEU with LEU. Arrangements for verifying this process are already in place between Russia and the US.

26 For detailed discussion see Bieniawsk.

concern disclosure of sensitive information, the uniqueness of the radiation signatures and the alteration of signatures during the dismantlement process.[27]

In reality, arrangements for the verified dismantlement of nuclear warheads might be more complicated (though far from insoluble) if dismantlement takes place in a facility still used for warhead production and maintenance. A minimum level of remanufacturing and reconditioning of warheads will continue in each of the nuclear weapon states until a decision is taken to disarm completely. The US Pantex Plant, near Amarillo, Texas, for instance, might be used for dismantlement and maintenance operations simultaneously, as might the UK's nuclear weapons research laboratory, Atomic Weapons Establishment (AWE) Aldermaston, if the UK's nuclear arsenal is dismantled in stages.

The criteria against which potential dismantlement schemes will be evaluated include the confidence the scheme gives that warheads are being dismantled as stated, the danger of inadvertent loss of classified information and the scheme's international negotiability. More mundane considerations will be the cost of inspections and, while the facility continues to be used for routine maintenance of warheads, the impact on operations.[28] The US Department of Energy has made a detailed study of options for dismantling warheads with differing levels of verification at the Pantex Plant, currently the only facility in the US authorised to disassemble nuclear warheads.[29] The other nuclear weapon states should commission similar studies.

To minimise the risk of disclosing sensitive information, and possibly to demonstrate a commitment to disarmament, the nuclear weapon states might also wish to evaluate the option of constructing new facilities to accommodate the verified dismantlement of warheads. The DOE has already carried out a study of the suitability of a newly-constructed facility at the Nevada Test Site, known as the Device Assembly Facility, for use as a dedicated dismantling plant.

Last, there is some debate over whether it would be worthwhile verifying the destruction of non-nuclear components of warheads. On the one hand, it is argued

27 Gerald P. Kiernan, Thomas P. Gosnell, M. William Johnson, and Hugh L. Scott, 'Interim Technical Report on Radiation Signatures for Monitoring Nuclear-Warhead Dismantlement' in Bieniawski.
28 Bieniawski.
29 Bieniawski.

that these parts could easily be replaced clandestinely, while on the other, that monitoring of the destruction of non-nuclear components would 'add to the preponderance of evidence that functional nuclear warheads are being dismantled'.[30]

Summing up, many of the technologies and techniques needed for verifying the elimination of nuclear warheads have been worked out at a general level. Research has been mostly carried out in official and semi-official studies by US organisations. While it is essential that these techniques be refined and improved, what is most important now, if disarmament is to proceed expeditiously, is for each of the nuclear weapon states themselves to study the central verification problems and requirements in order to identify particular techniques and approaches that they are willing to endorse.[31] They should study the generic techniques for verifying warhead dismantlement, such as warhead authentication and chain-of-custody arrangements, and give detailed consideration to the logistics of dismantling the warheads in their respective stockpiles, including, for example, the practicalities of accommodating international verification at their potential dismantlement facilities.

Whenever possible, verification research should involve international collaboration, both to perfect verification techniques and to build confidence in the disarmament process. The arrangements for verifying the transition to a nuclear weapon-free world will have to be negotiated; it would be useful for nations to develop verification techniques co-operatively so that the eventual treaty negotiations are not hampered by technical disagreements. [32]

If verification and transparency measures are included in international nuclear disarmament treaties—as they will for START III and subsequent bilateral agreements—the states involved will have to carry out R&D and practical preparations, such as have been begun in the US. Introducing transparency and verification into national nuclear weapons programmes might have a significant

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30 Bieniawski.

31 In 1998 the UK government made a start, announcing that: 'Britain has only a very limited capability at present to verify the reduction and elimination of nuclear weapons. A programme is therefore being set in hand to develop expertise in this area, drawing in particular on the skills of specialists at the Atomic Weapons Establishment'. See *Strategic Defence Review*. Cm 3999. HMSO. London July 1998. Supporting Essay Five: 'Deterrence, Arms Control and Proliferation', para. 30.

32 Discussing technology can also have a role in maintaining continuity in negotiations when progress is stalled because one side does not have clear political instructions. There was much discussion about the use of tags and seals in START, for example, which came to nothing. The lab-to-lab contacts have, to some extent, served such a function, through the recent period of strained US-Russia relations.

financial cost, although research and ingenuity might reduce this. Early investments in these fields and sharing of the results would be very useful.

3. Verifying Compliance with a Nuclear Weapons Convention: Future Trends and Possibilities

By far the hardest verification problem facing nuclear disarmament is the detection of illicit acquisition or retention of nuclear weapons. This is an area that would benefit from further study by each of the nuclear weapon states and as many other nations as are willing to devote resources to supporting nuclear disarmament.

With respect to detecting potential cheating by the current nuclear weapon states, the main verification problem will be establishing that neither warheads nor materials have been secreted away before the disarmament agreement enters into force. As far back as the early 1960s, when stockpiles were much smaller than today, a British analysis of controls on fissile material, based on a study of the UK's nuclear resources as they were then, concluded: .[33]

As far as the major nuclear powers are concerned, the control problem of the secret plant would be small compared with the problem of clandestine retention of fissile material

And a JASON[34] study published in 1993 concludes that 'one can never count on finding clandestine warheads'.[35] Steve Fetter goes further, saying that:[36]

from a purely technical point of view, it would not be difficult to hide the existence of a few dozen (or perhaps even a few hundred) nuclear devices from inspectors.

Some reassurance might be gained from attempts to reconstruct the complete history of a nation's nuclear programme from the declarations it makes, in order to check the warhead and fissile material declarations for internal consistency and to reconcile the declarations with intelligence data. Yet such an enterprise could turn out to be a mixed blessing, for it would surely reveal uncertainties and inconsistencies in the declaration. It might not matter that, in all probability,

33 'Technical Possibility of International Control of Fissile Material Production'. British Paper Submitted to the Eighteen Nation Disarmament Committee, August 31, 1962, ENDC document ENDC/60, Aug. 31, and Corr. 1, Nov. 27, 1962.
34 The JASON Committee of academic experts in 1994 completed a study on science-based stockpile stewardship of the US nuclear arsenal for the DOE.
35 Verification of Dismantlement of Nuclear Warheads and Controls on Nuclear Materials, JASON Study, January 1993, reported in Bieniawski.
36 Fetter, p. 23.

innocent explanations exist for such discrepancies; they could still be used to stall progress in disarmament. Investigative techniques used for 'nuclear archaeology,' whereby physical evidence is collected to verify declarations (samples taken from nuclear reactors, for example, in order to determine, within certain bounds, the total quantity of plutonium produced in the reactor), might also be of doubtful value, for the same reason.[37] On the positive side, an open and co-operative approach from the nuclear weapon states to establishing initial fissile material and warhead inventories, as a base-line from which international disarmament can proceed, would be likely to have a helpful impact on the disarmament process.

The British analysis referred to above sets out in some detail the multiple difficulties that would have faced any nation attempting to establish, with a useful degree of certainty, the quantity of fissile material produced in the UK by 1962. The inherent uncertainties have multiplied many times with the passage of nearly forty years, both on account of the increasing scale of the verification task, and because many of the senior managers in the early years of the nuclear programme, without whom it might be impossible to resolve particular controversies, are no longer alive.

South Africa's nuclear disarmament has provided the only practical experience of attempting to verify the quantity of fissile material that a nation has produced outside safeguards. In 1991 the IAEA was given 20 years of records to analyse. Although tests were made to establish that production records, for example, were authentic, it proved difficult to confirm the quantity of highly-enriched uranium produced at South Africa's enrichment facility.[38] Hans Blix, then Director General of the IAEA, concluded in a speech to the 1995 NPT Review and Extension Conference that.[39]

> [E]ven in the case where the Agency has been shown the most extensive co-operation and openness and has conducted the most extensive inspections, it cannot positively affirm that a declaration presented is correct and complete. It can only report that after very thorough verification, nothing has been found suggesting the contrary

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37 See, for example, ENDC/60. See also Steve Fetter, 'Nuclear Archaeology: Verifying Declarations of Fissile-Material Production', *Science and Global Security*, vol. 3, nos 3-4, 1993.

38 Waldo Stumpf, 'South Africa's Nuclear Weapons Program: From Deterrence to Dismantlement.' *Arms Control Today*, December 1995/January 1996, pp. 3-8.

39 Statement by Hans Blix, Director General of the IAEA, Review and Extension Conference of the Non-Proliferation of Nuclear Weapons, New York, in April 1995] (See http://www.iaea.org/worldatom/inforesource/dgspeeches/dgsp1995n06.html) Note, however, that in 1993 the Parties to the Treaty on the IAEA General Conference accepted that South Africa had made a complete declaration of facilities and materials.

It is worth considering that the uncertainty exists despite the fact that the South African programme was small scale, producing only six warheads. About 1,000 persons worked on the project, with roughly 250 involved at any one time. Waldo Stumpf, Director of the Atomic Energy Corporation of South Africa, makes an upper estimate of the total cost of the programme as about $US500m (at historical exchange rates)—a tiny fraction of comparable expenditure in the UK, France or China, let alone Russia or the US.

With respect to a nation attempting to violate a nuclear weapons convention by building and operating a secret production plant, the existence of any large plant would be obvious to national technical means (NTM),[40] so the problem is detecting a small-scale, clandestine nuclear programme developing one or a few nuclear weapons. Currently, this issue is associated mainly with the objective of deterring further horizontal proliferation of nuclear weapons. Like the illegal concealment of warheads or materials, this is a difficult problem, and one that might, moreover, become even harder as technology, such as laser enrichment of uranium, advances.

The potential acquisition of small clandestine arsenals by certain nations will probably be seen as an increasingly menacing threat when the current nuclear weapon states reduce their arsenals to low levels. As disarmament continues, there will be a need for technologies that can be used in international monitoring by organisations such as the IAEA, and for technologies that provide the best possible information-gathering capability for national intelligence services. In this connection, the nuclear weapon states have probably all studied the potential for detecting clandestine nuclear activities, based on extrapolations of their own industrial experience.[41]

40 For example, remote sensing by satellite or by aircraft under an Open Skies regime.

41 In the UK, for example, Exercise Overture was a military intelligence exercise, which began in the 1960s and ran for many years, trying to divine what radiation detected outside a facility could reveal about the facility. It researched the possibility of identifying nuclear facilities, and their activities, through analysis of environmental samples. Experiments were done on Britain's nuclear facilities, with the aim of then using the techniques as an espionage tool against the Soviet Union's nuclear programme. The work was carried out by the UK's nuclear weapons research laboratory, AWE Aldermaston, which continues defence intelligence work on monitoring nuclear proliferation, and has the best facilities in the UK for detecting minute quantities of radionuclides.

Looked at from this abstract technological perspective, therefore, the indications are that, in theory, it will be possible for an industrialised country to circumvent any international nuclear disarmament regime. It might do so either by sequestering a number of warheads or a quantity of fissile material before the agreement enters into force or by the clandestine manufacture of nuclear warheads after the agreement is in place.

This is not a problem that can be solved by verification alone. Verification does, though, have a very important role in building confidence in a disarmament *process*. Verification reduces the uncertainties inherent in disarmament and so increases the attractions of disarming as compared with the alternative of continuing to rely on nuclear deterrence.

Moreover, nuclear disarmament is likely to take years, as already discussed, and verification possibilities could change significantly in this period. For the remainder of the report, therefore, it is appropriate to discuss some of the main factors that might bear on the attainable standard of verification some years hence. Accordingly, we turn now to considering the potential impact of the trend towards greater openness and of improving technological verification capabilities, keeping always in mind that anticipating the future is rather speculative.

Increasing Openness

The general movement towards increased openness in the world is the trend likely to have the greatest impact on the possibility of verifying nuclear disarmament. With respect to eliminating nuclear weapons, openness is being increased directly through the negotiation of international treaties with inspection regimes and other confidence-building measures, and indirectly through the general increase in international activities, based on electronic communications and high speed travel. In addition, technological developments in areas such as satellite observation and the Internet are making attempts to maintain excessive secrecy increasingly problematic for every nation.

Intrusive Arms Control

During the past 30 years (that is to say, since the NPT came into force), the scope for intrusive arms control has been transformed. The increased degree of openness remains insufficient, however, to support nuclear reductions to low levels of nuclear weapons, let alone zero. It is important to promote still greater openness through arms control and other means. In particular, greater openness is needed at the national nuclear weapons complexes and generally in nuclear science research.

From the beginning of the nuclear age, openness has been a key to progress in nuclear disarmament. The many proposals for international controls on nuclear activities made immediately after the Second World War envisaged intrusions on national sovereignty completely unacceptable to the Soviet Union and probably to the US and other nations as well.

Co-operative nuclear arms control did not begin until the 1960s when the US, the UK and the Soviet Union worked together to ban nuclear testing. Herbert York writes that the second major American purpose in trying to negotiate a test ban (the first being to take a first practical step to reverse the arms race) was 'to begin the gradual process of opening up the Soviet Union... In modern terms, Eisenhower's second purpose was greater transparency'.[42]

But the transparency needed to monitor underground nuclear test explosions proved an impossible demand, leading to compromise on the 1963 Partial Test Ban Treaty. Co-operative arms control developed sporadically and very slowly for the next 30 years, until it was transformed in the second half of the 1980s and the first half of the 1990s with the 1986 Stockholm Accord, the 1987 INF Treaty, the 1990 Conventional Forces in Europe (CFE) treaty, the 1991 and 1993 START agreements, the 1993 Chemical Weapons Convention (CWC), the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT) and the IAEA's Strengthened Safeguards System, which began to be applied in 1997.

The START I and II agreements, limiting deployed strategic weapons and eliminating delivery systems, have detailed verification regimes, including on-site inspections in the US by Russian nationals and vice versa. START III is expected to include joint monitoring of nuclear warhead dismantlement and of warhead and fissile material inventories resulting from disarmament.

The CWC, which entered into force in 1997, provides for short-notice challenge inspections carried out by personnel of the Organization for the Prohibition of Chemical Weapons (OPCW) anywhere on the territory of a party suspected of non-compliance (in addition to routine inspections to verify declarations) This is the most intrusive verification regime of any disarmament treaty to date.[43] The CTBT, when it enters into force, will also have a global verification system, with arrangements for on-site inspection.[44]

Last, the Strengthened Safeguards System of the IAEA extends the function of safeguards from detecting a diversion of material from a declared facility in a member state of the NPT, to detecting diversion of material anywhere in that state. This makes IAEA safeguards more directly relevant to verifying nuclear disarmament. In terms of verification, INFCIRC/540, the new standard safeguards protocol, provides for better intelligence information to be given to the IAEA (principally from NTM, at least until commercial alternatives are available to the IAEA), makes use of advances in verification techniques such as environmental monitoring and remote surveillance, and signals the Agency's intention to utilise its longstanding right to carry out an inspection at any time in any place in a state with which it has a safeguards agreement.[45]

A nuclear weapons convention prohibiting the development and possession of nuclear weapons would use the same sort of provisions for monitoring and on-site

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42 Herbert York, 'The Road to Zero' in Maxwell Bruce and Tom Milne (eds), *Ending War The Force of Reason*, Macmillan, Basingstoke, 1999, p. 27.

43 Inspections are governed by 'managed access', whereby the host of an inspection can restrict access to areas of the site being inspected—in order to protect legitimate commercial or security information—but in doing so must still provide sufficient access to demonstrate compliance. All the nuclear weapon states have signed and ratified the convention. AWE Aldermaston in the UK, for example, has made preparations in case it should be subject to a challenge inspection under the CWC.

44 The main parts of the verification system will be the International Data Centre (IDC) in Vienna, the International Monitoring System (IMS), and National Data Centres (NDCs). The IMS is a global data collection system, consisting of 321 seismic, acoustic, hydroacoustic and radionuclide monitoring stations. It will transmit data to the IDC which will make this data available to state parties for assessment, which will be performed by NDCs. States parties are not obliged to set up NDCs, although the verification regime depends on such centres, since they are the only bodies that will have the expertise to analyse data from the IDC. States parties have the right to ask for an on-site inspection.

45 For further information see Suzanna van Moyland, 'The IAEA's Programme "93+2"', *Verification Matters*, Verification Technology Information Centre (VERTIC), London, Jan. 1997.

inspection as are now being implemented in these global arms control and disarmament treaties. It might also be that synergies could be achieved between global verification regimes.[46] David Fischer, the official historian of the IAEA, writes that:[47]

the steady accretion of intrusive arms control and disarmament treaties, and the almost universal acceptance of the NPT, now become permanent, have led to an evolution in the attitudes of most countries towards safeguards and a readiness to accept verification procedures that would have been found intolerable twenty-five years ago.

He concludes:

[T]he strengthened safeguards system will set new verification norms of general significance by codifying a novel set of measures that are internationally acceptable in order to verify that nations are complying with their arms control agreements. The comprehensive coverage that the strengthened system establishes, the far-reaching information it requires from states, the intrusive inspection that it authorises, and its acceptance by all the nuclear weapon states as well as by leading non-nuclear weapon states have set new precedents that significantly advance the frontiers of verification. Henceforth it should be more difficult for any state to resist intensive verification on the grounds that it entails an unacceptable infringement of national sovereignty.

However, it must not be supposed that in arms control and disarmament there is constant incremental development in the direction of increased openness between states. A 'backlash' can occur, in which standards of verification eventually included in a treaty regime are lower than previously accepted in the international community. Examples of 'backlash' can be seen in the verification provisions of the CWC and the negotiations on a verification protocol for the Biological Weapons Convention (BWC).[48]

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46 For some discussion on the potential for synergies between disarmament regimes, see David Fischer, 'The Risk of Proliferation: The Role of International Agencies,' in C.R. Hill, A. Mechelynck, G. Ripka and B. v.d. Zwaan (eds), *Nuclear Energy: Promise or Peril*, World Scientific Press, Singapore, forthcoming 1999; F.R. Cleminson, 'Multilateral On-going Monitoring and Verification of Compliance: Nurturing Cost-Effectiveness', paper presented at the Sixth ISODARCO Beijing Seminar on Arms Control, October 29-November 1, 1998; Marvin Miller, 'Verification Arrangements' in Canberra Commission on the Elimination of Nuclear Weapons, Background Papers: First meeting, Canberra, 23-25 January, 1996, Department of Foreign Affairs and Trade, Canberra, 1996.

47 David Fischer, 'Verification: The Contribution Likely to be made by IAEA 93+2,' in Blackaby and Milne.

48 It has been said that a backlash also occurred in the course of negotiating the CTBT, but this is not the case. The CTBT identification threshold, which dictates the required number of monitoring stations, was set at 1kt, higher than some hoped for and a matter of concern for some. However, there is a distinct chance that nuclear explosions with yields considerably below 1kt could be detected and identified by the IMS, meaning that the IMS might have the *effect* of deterring nuclear weapons explosions down to levels of a few hundred tonnes TNT equivalent. See for example 'Putting nuclear-test monitoring to the test,' A. Douglas *et al.*, Scientific Correspondence, *Nature*, vol. 398, 8 April, 1999, pp. 474-475.

After the CWC was opened for signature in 1993, for example, a 'backlash' was particularly evident in the US, where extensive criticism, focusing among other things on the verification regime, delayed ratification, despite administration and industry support for the convention. Typical reactions were that the prospective verification measures would be 'ineffective', they would give the US a false sense of security, and that the costs to the US of implementing the convention would be too high. These objections were orchestrated into a considerable challenge to US participation in the treaty, such that the US did not ratify until April 1997, only days before the convention entered into force. The ambiguity of US support is evident in the US domestic implementing legislation.

'Backlash' can be triggered in various ways, not just by worries about the financial costs of implementing intrusive verification measures, or about the possible loss of commercial or military secrets but by developments outside the disarmament agenda. For example the US/UK military strikes against Iraq in late 1998 and early 1999 and the NATO bombing of Kosovo delayed Russian ratification of START II. Also hindering Russian ratification of START II, as well as negatively influencing Chinese attitudes to co-operative arms control and disarmament, is the increasing US interest in developing ballistic missile defences.

Besides the danger of 'backlash', another caution when discussing the general development of international arms control is that to date no arms control or disarmament treaty has achieved universal adherence. Even adherence to the NPT, which has 187 states parties, is not universal. With India, Pakistan and Israel declining to sign,[49] universal membership in also not in prospect. Likewise, although a majority of nations have signed the CTBT, the CWC and the BWC,[50] there are significant hold-outs from these treaties too. Of the 44 countries that must ratify the CTBT before it can enter into force, India, Pakistan and North Korea have so far refused even to sign (although it may be that India and Pakistan will in the foreseeable future); and Egypt, Iraq, Libya, North Korea and Syria are among the nations that have still to sign either or both the chemical and biological weapons conventions.

49 The three other non-signatories, Cuba, the Cook Islands and Niue are located in nuclear weapon-free zones; the latter two in addition consider themselves bound by the adherence to the NPT by New Zealand, which administered these states when the NPT entered into force.

A nuclear weapons convention, in contrast, would have to have, for all practical purposes, universal adherence. It is most unlikely that the nuclear weapon states would sign a nuclear weapons convention if even one major nation refused to do so. Although universality is usually the goal in international treaty-making, for the moment the applicable legal principle is 'consent' not 'universality.' There is no mechanism for making a treaty automatically binding on all nations.[51] Even so, international law is not the major obstacle to nuclear disarmament; if the general will exists to eliminate nuclear weapons, it is argued, 'the legal means to do so can be fashioned, and can be as stringent as may be'.[52]

On balance, developments in arms control in the 1990s hold much promise for verifying nuclear disarmament. Indeed, the progress is all the more encouraging considering it has taken place against a background of a patently inequitable non-proliferation regime in which possession of nuclear weapons is permitted to a few and prohibited for the majority. The possibilities for verifying nuclear disarmament, and ensuring non-proliferation in the meantime, would surely improve dramatically were the nuclear weapon states to follow the recommendation of the Canberra Commission on the Elimination of Nuclear Weapons and they commit themselves unequivocally to the elimination of nuclear weapons as well as take some immediate practical actions to back up their words.[53]

International Collaboration on Verification R&D

One of the most effective means of building international confidence in nuclear disarmament would be to promote international collaboration on verification and other aspects of nuclear arms control, non-proliferation and disarmament among national nuclear weapons laboratories. Besides the increase in trust that accompanies greater openness, such collaboration would play an essential part in

50 At the time of writing, the CWC has 169 signatories (121 ratifications); the BWC has 159 signatories (141 ratifications); the CTBT has 152 signatories (29 ratifications).

51 For a discussion of the question of achieving universal membership of a nuclear weapons convention, see Maxwell Bruce, Horst Fischer and Thomas Mensah, 'A NWFW Regime: Treaty for the Abolition of Nuclear Weapons,' in Rotblat, Steinberger and Udgaonkar, pp. 121-122.

52 James Crawford and Philippe Sands, 'Legal Aspects of a Nuclear Weapons Convention', background paper prepared for the Canberra Commission on the Elimination of Nuclear Weapons, Department of Foreign Affairs and Trade, Canberra, 1996.

53 Canberra Commission, p. 11.

developing international standards and approved techniques for use in the disarmament process.

To illustrate the opportunities for international collaboration in arms control research, we consider those open to the US and UK. US nuclear weapons laboratories already collaborate extensively with nuclear facilities in Russia on many aspects of verification. They have also established embryonic nuclear arms control projects with China. It would be easy for them to set up collaborative work with the UK and France should these nations express interest in such an arrangement.

Although the UK Atomic Weapons Establishment (AWE) does not have comparable international programmes to the US laboratories, the UK Ministry of Defence, which tasks AWE, has recently indicated that it wants AWE both to expand its involvement in verification work and to increase its links with other bodies in the UK and abroad. Hunting-BRAE, the industrial consortium that has been running AWE since 1993 (the contract comes up for renewal in April 2000), has made a small start in promoting international links. In September 1997 it organised an international workshop on shock-wave physics at Oxford University, attended by, among others from around the world, a sizeable delegation of Russian nuclear scientists, who visited Aldermaston during their stay. A similar conference is planned for the northern summer of 1999 on materials science.

US-Russia collaboration

Collaboration between US and Soviet/Russian nuclear scientists has increased steadily since the two countries carried out Joint Verification Experiments (JVEs) in 1988 to secure ratification of the Threshold Test Ban Treaty (TTBT). The JVEs allowed on-site measurement of the yield of nuclear explosions at the Nevada and Semipalatinsk test sites (which were then compared with off-site measurements). This led to the ratification of the treaty some 16 years after it was signed. (The TTBT had remained unratified for so long mainly because of US suspicions about Soviet non-compliance.)

In 1991 the US Congress passed legislation allocating funds to help the Soviet Union destroy its weapons of mass destruction and to develop non-proliferation safeguards. The Cooperative Threat Reduction Program, known also as the Nunn-Lugar programme (after Senators Sam Nunn and Richard Lugar who initiated the legislation), made progress with destruction of missiles and missile silos as agreed in START I, but projects to increase security at facilities containing nuclear materials were slow to begin. Against the background of the Nunn-Lugar government-to-government efforts, US and Russian nuclear weapons laboratories also initiated scientific exchanges. In 1994 this provided a basis for what has now become a large 'lab-to-lab' programme to 'reduce the threat of nuclear proliferation and nuclear terrorism by rapidly improving the security of all weapons-usable nuclear material in forms other than nuclear weapons in Russia, the NIS [Newly-Independent States], and the Baltic States'.[54]

The US Department of Energy national laboratories co-operate directly with nuclear institutes in the former Soviet Union (FSU). Areas covered under the programme include transparency measures for warhead and material storage; nuclear material protection, control and accounting (MPC&A); plutonium disposition; and joint scientific research unrelated to nuclear weapons. By 1998 the DoE was working at around 60 sites in the FSU, with a programme budget of $US137 million, scheduled to increase to around $US160 million in 1999.

In its short life to date, the lab-to-lab programme has engendered considerable confidence between the nuclear establishments of the two countries. Although classified topics are avoided, the scientists visit one another's laboratories, see the infrastructure and facilities available to their counterparts and form working and personal relationships with their opposite numbers.

US/Russian technical collaboration has not, however, been without problems. In particular, co-operation has so far foundered on most of the more sensitive questions of increasing transparency in connection with warheads and fissile materials. Progress in these technical discussions is still hampered by the soured political relationship between the two countries. But were the political context to improve—notwithstanding that entrenched habits of secrecy would still have to be overcome—these technical interactions might be useful steps towards the openness

54 *Partnership for Nuclear Security*, Department of Energy Nuclear Material Security Task Force, Washington DC., December 1997, p. xii.

needed for START III and beyond. Indeed, what little progress has been made in the latter part of the 1990s in bilateral transparency and verification arrangements has come through the lab-to-lab programme.

US-China collaboration

There are tentative attempts underway in the DoE to initiate joint work with China in some technical areas of arms control. There have been some technical exchanges on seismology and the US staged a material control and accounting demonstration at a facility in China in 1998. The DoE programmes with China are still small by US standards, receiving about $US1.5 million in 1998.[55]

US-UK and US-France collaboration

The arrangements for exchange of classified nuclear information between the US and both the UK and France (in particular those with the UK) provide scope for in-depth collaboration on nuclear arms control and disarmament such as is not possible between the other nuclear weapon states. US-UK collaboration could be used to test sensitive verification procedures, including for example warhead authentication techniques, detailed data exchanges and arrangements for direct observation of dismantlement processes.

The UK has just set up a pilot programme at AWE to research verification of disarmament. It is likely that when this work has taken a firmer hold, one or more verification Joint Working Groups ('JOWOGs'—periodic technical discussions between representatives of the US and UK nuclear weapons laboratories) will be established.[56]

UK-Russia collaboration

Britain could (and should as a matter of urgency) join the US in working with Russia to improve safeguards on nuclear materials. The US work on MPC&A is extensive, but the scale of the effort is limited by the number of available personnel.

55 Progress is currently being made difficult, on the US side, by recent allegations of espionage by Chinese scientists working at DoE laboratories.

56 For a more detailed discussion see Tom Milne and Henrietta Wilson, *Verifying Nuclear Disarmamen: A Role for AWE Aldermaston*, British Pugwash Group, London, 1999.

Additional co-ordinated contributions from other countries are needed. The UK's current contributions, described later in this report, are minimal.

Although there may in some cases be resistance on the Russian side to collaboration with the UK, a second tier nuclear weapon state, compared with the US ('side by side as equals'), this can undoubtedly be overcome, particularly if the UK has funds to bring to the process. The UK has much relevant expertise, and could second skilled staff to Russia; by doing so, it would make a contribution to future verification work by building confidence and promoting openness.

It is desirable that Anglo-Russian collaboration is initiated on other aspects of arms control and disarmament. It is noteworthy that Russian nuclear weapons laboratories are beginning to set up discrete arms control centres, which will facilitate establishment of collaboration in this field.

UK-France collaboration

There should not be any technical or security obstacles to joint work on, for example, test monitoring (where the principal French expertise on nuclear arms control and disarmament currently resides) or any other aspect of nuclear arms control and disarmament.

Multilateral collaboration among the nuclear weapon states

In addition to bilateral arrangements between the nuclear weapon states, collaboration between all five should be sought whenever possible. The final report of the Steering Committee of the Project on Eliminating Weapons of Mass Destruction at the Henry L. Stimson Center, *An American Legacy: Building a Nuclear-Weapon-Free World*, recommends that 'working with Russia, the US should try to expand the dialogue on nuclear threat reduction to include all nuclear weapon states'.[57] The report continues:[58]

Such a dialogue might begin with consideration of important technical issues, including the five countries' respective mechanisms to ensure the safety and security

57 *An American Legacy*, p. 10.
58 *An American Legacy*, p. 10.

of nuclear materials and weapons, and the establishment of common systems and standards for accounting for all nuclear materials.

If India, Pakistan and Israel can also be engaged in discussions or collaborative research on verification, so much the better. These nations will wish to concern themselves with many of the same arms control and verification issues. International engagement may be possible in technical areas long before overt political negotiations.

Looking several years ahead at a world in which there might be much greater political commitment to disarmament than today, the possibility arises of securing global agreement to ban nuclear secrecy, as advocated, for instance, by Theodore Taylor.[59] A high degree of openness will be needed in any disarmament scenario, but the most radical option is that it be made law that all research and development on nuclear energy be conducted openly. Such an agreement would include the obvious proviso that the relatively few facts about constructing nuclear weapons that are not generally known should remain out of the public domain.

In the military sector, a ban on nuclear secrecy would alleviate concerns that new nuclear weapons concepts are, for example, being worked out under the cover of residual weapons programmes, such as the US programme of 'science-based' stockpile stewardship or France's Mégajoules laser project. The belief, strongly held in some quarters, that the US is circumventing the CTBT, is currently one of the obstacles to entry-into-force of the treaty.

In the civilian sector, a ban on nuclear secrecy would alleviate significant concerns that a nation could conceal a weapons programme within ostensibly non-military R&D. For example, research on inertial confinement fusion (one of the main activities planned at the National Ignition Facility being built at the Lawrence Livermore National Laboratory), provides, in effect, the means for a country to develop or maintain expertise in a range of scientific fields related to nuclear weapons physics. It is important for such research to be carried out openly.[60]

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59 For an elaboration of this idea, see Theodore B. Taylor, 'Global Abolition of Nuclear Weapons and Nuclear Secrecy in the 1990s', paper presented at Pugwash Meeting N. 185a. *Desirability and Feasibility of a Nuclear Weapon-Free World*, London, 14-16 December, 1991.

60 Christopher E. Paine, Thomas B. Cochran and Robert S. Norris, 'Current Political Realities Confronting the Transition to a Nuclear-Weapon-Free World.' Canberra Commission on the Elimination of Nuclear Weapons, Background Papers, First meeting, Canberra, 23-25 January 1996, pp. 155-176.

In short, Taylor argues, 'a verified ban on all nuclear secrecy could go a long way towards assuring that whatever roles peaceful uses of nuclear energy may play in the future, they are developed and implemented with full public disclosure of their character and purpose'. In response to the inevitable opposition from wishing to protect patents and commercial industrial processes, Taylor argues that 'the discontinuities in the destructive potential of technology represented by release of nuclear energy are so great that many aspects of this technology must be treated differently from other technologies for industrial development or production'.

The potential for diverting nuclear weapons materials from a civil nuclear power programme will always exist. The future of nuclear power generation will have a major bearing on progress towards a nuclear weapon-free world, including the question of verification. The degree of the danger posed by civil nuclear programmes will depend on the safeguards imposed on them, the types of fuel cycle they employ, their scale and their type of ownership (private, national or international). In any scenario, civilian nuclear power will produce weapons-usable materials (it has long been established that plutonium of almost any isotopic composition can be used to manufacture nuclear weapons), make concealing an illicit nuclear weapons programme easier and maintain a country's expertise in nuclear physics. The other side of the coin is that given the role of nuclear energy in electricity generation, and concern about greenhouse gases produced by carbon fuels, linking nuclear disarmament to the phasing out of nuclear power may be a 'hurdle too far'. If civil nuclear power remains in use in a nuclear weapon-free world, its most dangerous aspects, from a weapons development perspective, may still have to be foregone or placed under international control.[61]

Societal Verification

A ban on nuclear secrecy, associated by the general public with a nuclear weapon-free world, should also help encourage the general public to 'blow the whistle' on any infraction of the nuclear weapons convention about which they become aware.

The authors also note that Argentina, Brazil, Pakistan, South Korea and Taiwan, each of which during the 1970s sought reprocessing technology ostensibly for civilian purposes, had secret nuclear weapons programmes.

61 For a summary of some of the main issues see Paine, Cochran and Norris.

Establishing openness at national nuclear weapons establishments and bringing nuclear weapons scientists from different countries into regular contact should also, promote 'societal verification'.

Encouraging verification by society was discussed immediately after World War II when there was intense interest in world government and general and complete disarmament. The concept of societal verification has been revived in recent years following the renewed interest in nuclear disarmament. It is seen as a necessary complement to technological means of verification.[62]

Measures for societal verification of nuclear disarmament should be formally written into the convention banning nuclear weapons. Every nation should also be obliged to enact domestic legislation requiring its citizens to inform an international authority about any activity that contravenes the convention.[63] Arrangements would be needed to guarantee whistleblowers political asylum. In 1945, six weeks after the bombing of Hiroshima, Leo Szilard suggested that the necessary first step for verification of nuclear arms control agreements would be to 'guarantee immunity to scientists and engineers everywhere in the world in case they should report violations... ' With a Bill of Rights for scientists and engineers they would become 'the guardians of the international arrangements relating to the control of atomic energy', Szilard argued.[64]

It is said in criticism of 'citizen reporting' that it would work best where it was least needed— in open, democratic countries with a strong free press—and would be unlikely to work in countries where it would have greater potential value— closed societies with repressive regimes. Even if true,[65] there are at least two possible points

62 See, Hanna Newcombe, 'Citizen Reporting as a Method of Arms Control Verification,' *Proceedings of the Fortieth Pugwash Conference on Science and World Affairs: Towards a Secure World in the Twenty-First Century*, Pugwash Conferences, London, 1991, pp. 321-331; Joseph Rotblat, 'Societal Verification' in Rotblat, Steinberger and Udgaonkar, pp. 103-118; Frank Blackaby, 'Societal Verification' in Rotblat (ed.), pp. 101-113.

63 The CWC explicitly requires national legislation, going some way towards this. Article VII reads: 'Each State Party shall, in accordance with its constitutional processes, adopt the necessary measures to implement its obligations under this Convention. In particular, it shall: (a) Prohibit natural and legal persons anywhere on its territory...from undertaking any activity prohibited to a State Party under this Convention, including enacting penal legislation with respect to such activity . . .'

64 Quoted in . William Lanouette (with Bela Szilard), *Genius in the Shadows: A Biography of Leo Szilard, The Man Behind the Bomb*, University of Chicago Press, Chicago, 1992, pp. 283-284.

65 As Steve Fetter points out, while citizen's reporting depends mostly on a country's political culture, the oppressive governments of Iraq and North Korea have suffered high-level defectors. See *Verifying Nuclear Disarmament*, p. 24. for example, Saddam's son-in-law, Hussein Kamel, defected in 1995, revealing details of the nuclear weapons programme. Khidhir Hamza, a senior scientist on the programme

in mitigation. One is that it takes only one person to 'blow the whistle'. Throughout history there have been people prepared to take great personal risks for causes they believe in. The other is that it is increasingly easy to convey information in confidence to international authorities from any country in the world, using electronic communications and encryption devices. Citizen reporting cannot be controlled by any political regime.

The potential effectiveness of societal verification obviously cannot be quantified and therefore societal verification could at most supplement the main verification regime. An international agreement to eliminate nuclear weapons would not be based on the possibility of whistle-blowing alone.

Establishing societal verification as a political norm would, however, represent an additional deterrent to a nation contemplating breaking out of an NWFW regime. And in some circumstances, societal verification might be one of the main deterrents to a nation contemplating cheating. The UK study of evasion scenarios facing a fissile materials 'Control Organization', referred to earlier in this report, concluded:[66]

> A violator seeking to secrete the maximum possible amount of plutonium and U235 [Uranium 235] which we consider could escape detection by the Control Organization would have to undertake a large and complex series of falsifications, and would have to involve several hundred people in technical organisations. Even though the risk of the violator being caught by technical considerations would be small, the violator must also be prepared to accept the risk that some of the staff involved in the forgeries would reveal their part in the forgeries to the Control Organization.

Similarly, a clandestine weapons production programme would involve many scientists and engineers, making whistle-blowing a distinct possibility and consequently a deterrent to cheating. A smaller number of trained engineers would be needed to maintain a clandestine stockpile of warheads (possibly selected or designed to require a minimum of maintenance), so leaked information in this scenario would be less likely, assuming that the chances of whistle-blowing are correlated to the number of persons privy to the secret.

throughout its existence, who also defected in 1995, describes the programme's history in 'Inside Saddam's Secret Nuclear Program', *Bulletin of the Atomic Scientists*, Sept./Oct. 1998, pp. 26-33.

66 British Paper Submitted to the Eighteen Nation Disarmament committee: Technical Possibility of International Control of Fissile Material Production, 31 Aug. 1962, ENDC/60, 31 Aug. 1962 and Corr. 1, 27 Nov. 1962.

Alongside general citizen reporting, the scientific community could set up an organised monitoring system. For example, a scientific watchdog could track the careers and publications (or lack thereof) by scientists with, say, postgraduate training in nuclear physics or nuclear engineering. In this connection it would be interesting to try to establish, retrospectively, whether such monitoring would have detected the South African and Iraqi nuclear programmes. According to Khidir Hamza, senior scientist on the Iraqi programme, Iraq's main nuclear research centre, Al-Tuwaitha, which housed thousands of scientists and technicians for two decades, produced only a handful of published scientific articles in this period. Hamza continues: 'We worried about how this would look to the IAEA or to foreign intelligence organisations. But to our relief, no one ever raised questions...'[67]

Development Of Verification Technologies And Techniques

Alongside increased openness, a second trend that could have a significant effect on the possibility of verifying nuclear disarmament is the improvement of technological verification capabilities both on account of general technological advance and the work of dedicated verification R&D programmes at national nuclear weapons laboratories and elsewhere.

For over thirty years technological progress has led to more effective and reliable verification at declining cost. Can this trend be expected to continue? Obviously, existing technologies will be refined, both for detection and for evading detection, but is progress in verification capabilities likely to be incremental or might it be revolutionary? Another question is: can progress in verification technology be expected to be proportional to the resources invested? Is the US, for example, already close to the point of diminishing returns?

Also relevant is whether the prospects for nuclear disarmament would improve if the research effort on verifying nuclear disarmament was spread more widely among different nations. The current global expenditure on verification R&D is

67 See 'Inside Saddam's Secret Nuclear Program' A total of about 1000 persons worked on the South African atomic weapons project, with roughly 250 personnel involved at any one time. See Stumpf, pp. 3-8. Any conclusion, based on retrospective analysis, that a scientific watchdog would have detected the clandestine South African and Iraqi programmes, ought to be assessed sceptically, however, since reasoning backwards from the fact of a clandestine programme, is quite unlike a blind search for potential

concentrated heavily in the US: what would be the impact of a more diversified, multinational body of research on verification technology and techniques?

Global Patterns of Expenditure on Verification R&D

To discuss the potential for improvement of technical verification capabilities, it is useful first to outline global patterns of expenditure on verification R&D. The scale of existing work, its geographical location, the way the work is organised, and the subject matter studied, suggest where the scope lies for improvement and expansion of efforts world-wide.

When looking at global expenditure on verification R&D, it is natural to start in the US, where verification and other aspects of nuclear arms control, non-proliferation and disarmament are major programmes at both the Department of Energy (DoE) and the Department of Defense (DoD).

The largest block of funding specifically allocated to arms control, non-proliferation and disarmament is that of the Office of Non-Proliferation and National Security within the Department of Energy (DoE/NN). The DoE/NN funding request for FY1999 amounts to roughly $US700 million. About a third of this money is for verification R&D; another third is for co-operative programmes with states of the former Soviet Union, including MPC&A work and mutual transparency studies; DoE/NN also provides sizeable funding to such areas as international nuclear safeguards, technical support for monitoring Iraqi facilities and domestic materials safeguards and security. Another significant segment of DoE funding for arms control (about $US100 million a year) is spent on materials disposition studies, which includes co-operative work with Russia.

All of the DOE national laboratories are involved in verification work, the largest contribution being made by the three main nuclear weapons laboratories–Los Alamos, Lawrence Livermore and Sandia—each of which has a specialised non-proliferation and arms control division.

cheating. It also has to face the difficult problem of anticipating the evasive actions that might have been taken had the watchdog been in existence at the time.

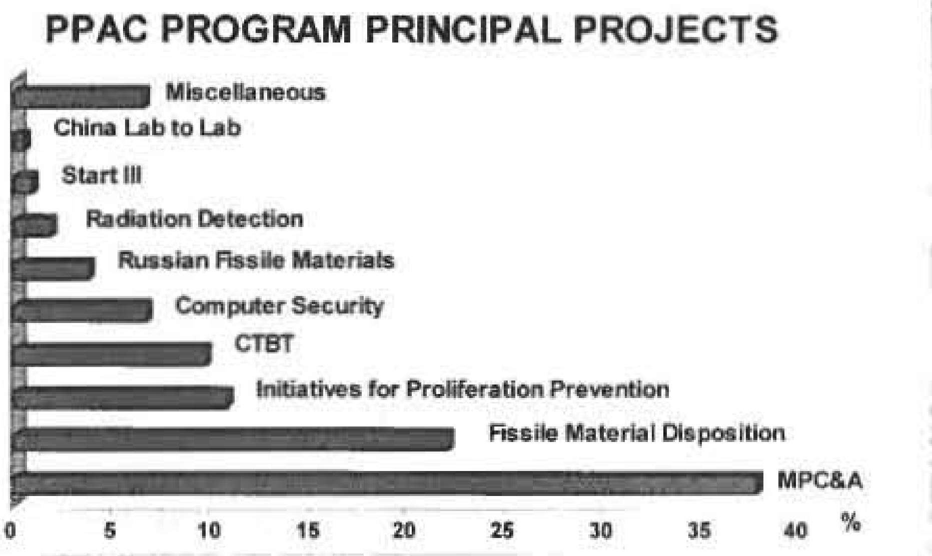
At Los Alamos National Laboratory, for example, there is the Non-Proliferation and International Security Division, employing about 700 staff, with a budget for FY1998 of around $US140 million (see box).

> **NON-PROLIFERATION AND INTERNATIONAL SECURITY DIVISION LOS ALAMOS NATIONAL LABORATORY**
>
> **MAIN PROGRAMMES - KEY AREAS**
>
> NON-PROLIFERATION AND ARMS CONTROL
> Irreversible nuclear arms reductions; MPC&A, domestically and in fSU [former Soviet Union]; detecting proliferation; countering nuclear smuggling; treaty development and implementation; export controls; IAEA programmes
>
> RESEARCH AND DEVELOPMENT
> Capabilities for detecting and characterizing proliferation; nuclear test detection
>
> INTERNATIONAL TECHNOLOGY
> Intelligence— assessment of foreign nuclear programmes etc.
>
> CENTER FOR INTERNATIONAL SECURITY AFFAIRS
> co-ordinating interactions with Russia; developing interactions with China

At Lawrence Livermore National Laboratory there is the Proliferation Prevention and Arms Control (PPAC) programme, which is part of the Non-Proliferation, Arms Control and International Security directorate. The PPAC program has an annual budget of $US100 million and employs 160 people.[68] It include the IPP, a programme aimed at redirecting the efforts of scientists in the former Soviet Union who have been involved in weapons development.)

68 The explanation for the apparently high per capita cost of the programme ($US625,000 per employee) is that the programme budget includes $US40 million spent on contracts in the former Soviet Union, $US10 million for contracts with other DoE laboratories on fissile material disposition work and a large budget for travel.

PPAC Programme: Principal Projects



The Department of Defense FY1999 budget request includes roughly $US350 million for assistance to the former Soviet Union in the elimination or secure storage of nuclear and chemical weapons; funding for the activities of the former On-site Inspection Agency (OSIA) (roughly $US100 million);[69] funding for the Defense Special Weapons Agency (formerly the Defense Nuclear Agency), which is involved in some arms control research, including, for example, work on detecting underground nuclear facilities; and considerable additional funding for verification R&D buried in huge procurement and RDT&E (research, development, testing and evaluation) budgets.

Verification/arms control funding also goes to the activities of the former Arms Control and Disarmament Agency,(ACDA)[70] and funding for verification is built into intelligence budgets, the detail and size of which are for the most part classified. This includes work to detect the theft and smuggling of nuclear materials and the development of specialised sensors and databases.

69 The OSIA was absorbed into the Defense Threat Reduction Agenc in October 1998.
70 ACDA was incorporated into the State Department in April 1999.

Last, there are a number of commercial firms in the US that develop, customise and market verification and monitoring technologies pioneered at the US national laboratories and elsewhere. A significant proportion of the technology used in international safeguards is provided by these firms. Canberra Industries, for example, located in Meriden, Connecticut, is the largest supplier of safeguards equipment to the IAEA, EURATOM (European Atomic Energy Community) and other safeguards agencies world-wide.

There is no central federal budget for verification in the US. Neither the General Accounting Office nor the Congressional Budget Office has integrated data on US arms control and verification spending. An attempt to construct a comprehensive picture of verification R&D in the US would be worthwhile.[71]

The Non-Proliferation and Arms Control Technology Working Group (NPAC TWG) has been established to co-ordinate US government-funded R&D in arms control and non-proliferation. As well as nuclear-weapons related work, this includes work on chemical and biological weapon detection, missile sensing, and landmines. The NPAC TWG co-ordinates $US2.8 billion annual expenditure, and estimates that there is an additional $US1.8 billion annual expenditure on of related work in the US.

It may be estimated, then, that in round numbers the DoE and DoD each have budgets of perhaps $US1 billion a year for verification and other aspects of nuclear arms control, non-proliferation and disarmament. Depending on what is included, the totality of federal support for 'verification' of nuclear disarmament in the US might be in the region of $US2-3 billion a year.

US expenditure on verification dwarfs that of the rest of the world. The relative importance of expenditure outside the US on verification, from the perspective of furthering the cause of nuclear disarmament, is, however, far greater than the absolute levels of funding imply. The reason for this is that nuclear disarmament is an international enterprise, requiring the participation of a range of countries. The potential benefits of increasing expenditure on verification in nations other than the

71 Perhaps this could be linked in some way with the US Nuclear Weapons Cost Study Project, carried out by the Brookings Institution. See Stephen I. Schwartz (ed.), *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*, Brookings Institution, 1998.

US deserve greater emphasis in discussions on the possibility of verifying nuclear disarmament.

As an illustration of the contrast between US involvement and the involvement of other nations, consider expenditure on verification R&D in the UK. The UK is an established nuclear weapon state; it does not have a military space programme, but has otherwise played a reasonably active role in international nuclear arms control.

The largest item of expenditure in the UK is the nuclear test monitoring programme, funded at about £1.5 million a year, divided between the AWE outstation at Blacknest, which has been involved in forensic seismology for forty years, and the British Geological Survey in Edinburgh, where the UK's National Data Centre to support the CTBT is located. AWE Aldermaston also contributes to defence intelligence work and the Ministry of Defence pays for radiochemical services from Aldermaston, which are used in support of IAEA safeguards—this other work amounts to perhaps £1 million a year.

The UK has a technical programme in support of the IAEA funded by the Department of Trade and Industry (DTI) and managed by the UK Atomic Energy Authority (UKAEA), with a budget in the region of £1.5-1.7 million a year.[72] Roughly two-thirds of the budget supports IAEA safeguards. The remaining third is spent on nuclear materials control work to assist DTI in the formation of policy on domestic and international safeguards. The primary recipients of safeguards money are British Nuclear Fuels (BNFL) and AEA Technology. The UK has also had a budget of £1.3m a year to supply personnel and equipment in response to requests from UNSCOM and the IAEA Action Team in Iraq. The nuclear component of this expenditure is relatively small.

Last, in the civil sector, the UK funds small-scale projects, mainly through British Nuclear Fuels, concentrated on enhancing safeguards at the Mayak reprocessing plant in Russia.[73] The MoD does not have any co-operative programmes with

[72] Personal communication from Maurice Ward, UK [Safeguards] Support Programme to IAEA, UKAEA, Risley, UK.
[73] G. Andrew (DTI), A. Barlow (FCO), M. Beaman (DTI), B. Burrows (BFL) and M. Ward (UKAEA), 'UK Cooperation with the Russian Federation and Kazakhstan in Nuclear Accountancy and Control', paper presented at European Safeguards Research and Development Association (ESARDA) symposium, 1995; G.S. Starodubtsev *et al.* ('Mayak'), G. Andrew (DTI) and R. Howsley *et al.* (BFL), 'Preliminary

Russia. In 1993 it provided 250 'supercontainers' for transportation of Russian warheads (for which AWE carried out some design work and acted as the prime contractor); MoD also supplied 20 heavy duty trucks, but has done nothing since.

In sum, the total annual expenditure on verification work in the UK amounts to a few million pounds, a fraction of one per cent of comparable expenditure in the US. Expenditure on nuclear verification in France and China is no greater. Larger arms control programmes are now being established in Russia, with start-up funding from the US.

The non-nuclear weapon states are only marginally involved in nuclear arms control and disarmament, mainly through national technical support programmes to IAEA safeguards. Argentina, Australia, Belgium, Canada, Finland, France, Hungary, Indonesia, Japan, the Netherlands and Sweden have safeguards programmes, but these are very minor undertakings, dispensing funding on the order of a million pounds a year or less. A number of non-nuclear weapon states have been active in verification research on nuclear test detection and the technical aspects of negotiation of the CTBT, including Australia, Canada, Germany, Israel, Japan, Norway and Sweden.

Just as there are no integrated data on funding of verification research in the US, so there is no reliable and integrated source of data on world-wide verification R&D. Research into world-wide funding of, verification R&D, covering the magnitude and sources of funds and patterns of expenditure (institutions, types of projects etc.), would provide a valuable resource to those working to promote nuclear disarmament. This brief survey is sufficient, however, to conclude that the field is dominated to an unhealthy extent by the US because of the paucity of effort elsewhere.

Scope For Expansion of Verification R&D

Ideally, a wide range of countries should devote a significant proportion of state-supported R&D to arms control verification, as currently is the case only in the

Results of Cooperation between the 'Mayak' Production Association and British Nuclear Fuels plc (BFL) in Nuclear Materials Control and Accountancy,' paper presented at a conference on Nuclear Material

US.[74] Such a redirection of scientific resources would not happen overnight, but a shift of this magnitude is feasible over a period of years. In the US, non-proliferation and arms control budgets at the DoE laboratories increased very rapidly following the end of the Cold War and in response to the crisis over safeguarding of nuclear materials in Russia. Looking ahead ten or twenty years, as in this report, there is enormous scope for the development of verification expertise outside the US.

A case can be made for increasing world-wide expenditure on verification of disarmament. The example of Britain can again be used to illustrate the general point. The British government no longer regards security as exclusively a military concern. The threat is no longer pictured in terms of an invasion of the British Isles. The problem is rather one of a miscellany of conflicts, most of them intra-state and posing no direct threat to Britain. Britain's security requires, therefore, that it does what it can to reduce the use of armed force world-wide and to take part in international military action.[75]

The promotion of world-wide measures of arms control and disarmament is one of the most effective ways of reducing the use of military force world-wide and reducing the threat from terrorist groups and aberrant national leaders acquiring weapons of mass destruction. For this reason, arms control and disarmament should not be treated, as they are now, as a minor appendage of security policy. To mitigate the danger of nuclear leakage in Russia, for example, the UK should offer vastly more to assist in the safeguarding of nuclear materials; this would involve secondment of British nuclear experts to Russia, indirectly assisting the verification process.

Production, Control and Accounting, Moscow, 1997.

74 US expenditure on verification and other aspects of nuclear arms control, non-proliferation and disarmament, which we estimate at $US2-3 billion a year, is a significant fraction of total US government-funded military R&D (about $US39 billion in 1995), and it is on the same order of magnitude as the annual expenditure of roughly $US4 billion on the stockpile stewardship programme, now the main nuclear programme at the DoE laboratories. For comparison, in the UK funding for verification of nuclear arms control and disarmament amounts to only a minuscule fraction of the roughly £2 billion a year of government-funded defence science and technology, and perhaps 1-2% of the £300 million a year budget of the AWE.

75 Also relevant to Britain's security, not least because of the nation's worries about proliferation in Iraq, and high-profile support for US-led military actions against Iraq, is the danger of nuclear materials 'leaking out' from the crumbling nuclear infrastructure in the former Soviet Union. Who can doubt that Saddam Hussein, having spent millions of pounds trying and failing to acquire nuclear weapons, is in the market for black market fissile material?

In 1995 the Foreign Affairs Committee of the House of commons in its report *UK Policy on Weapons Proliferation and Arms Control in the Post-Cold War Era* strongly endorsed the 'treaty-based regime approach to the non-proliferation of weapons of mass destruction'.[76] But this has not been reflected in a redistribution of resources from military R&D to verification R&D; indeed, verification and other aspects of arms control, non-proliferation and disarmament are not even recognised as a discrete issue for attention in national science policy. Compare this with the US, where President Bush first declared a state of national emergency triggered by the potential for proliferation of weapons of mass destruction in 1990, a position reiterated by President Clinton in 1994. Among the practical responses has been the establishment of the NIS division at Los Alamos and the PPAC program at Lawrence Livermore described above.

With limited state funds available for R&D in all nations, justifying an increase in funding for verification—in the UK as in any other country—requires demonstrating that R&D funds can be invested productively. This raises two questions. The first is whether current verification technology is open to significant improvement, in view of the amount of research already carried out in the US. The second is whether countries such as the UK could and should develop indigenous expertise in the field.

With respect to the first question, the general feeling at US DoE laboratories is that while there is no scope for a massive increase in expenditure on arms control, non-proliferation and disarmament, additional funds could be spent wisely. Take as an example nuclear test monitoring, which has long been studied and is a relatively mature field. The US has already produced sensors for test detection to be installed on the next generation of satellites, due for operation around 2002/3. The phenomena that are characteristic of a nuclear detonation are well known, so there are limits on new R&D that could sensibly be funded. In seismic and acoustic detection of nuclear tests, the basic phenomena are similarly well understood, but there is a need for much more detailed geological and meteorological information in order to apply advanced detection techniques. Continuing research is also needed on detecting, and distinguishing between, low magnitude seismic disturbances. In

76 UK Policy on Weapons Proliferation and Arms Control in the Post-Cold War Era. *Second Report of the Foreign Affairs Committee 1994-95, Volume I*, HMSO, London, 1995.

other areas, there is, for example, considerable scope for improvements in sensors for detecting nuclear facilities and signs of proliferation of weapons of mass destruction—including detecting traces of chemicals or finding means to detect underground structures. And while many of the current programmes at the US laboratories are due to decline early in the next century, in particular the MPC&A work in the former Soviet Union, there is no reason to suppose that new programmes, on warhead dismantlement for instance, will not grow to replace them.

To sum up, in the view of the program manger of verification R&D at Los Alamos, for the time being there is reason only to anticipate evolutionary progress, proportional to the available funding.[77] It might be added, as argued extensively in this report, that progress will also be determined by the degree of international collaboration achieved.

As we have already emphasised, however, the primary requirement is not an expansion of research in the US (desirable though this is) but increased research in other countries. Which brings us to the second question: could the UK, for example, set up a worthwhile verification research project of its own?

Of great importance to the UK, as for every country that participates in the preparations for warhead elimination, is to decide whether the associated verification meets its needs. Unless UK officials are informed about the whole range of technological verification possibilities, they will be liable to make bad decisions in future nuclear disarmament negotiations. UK scientists will have to advise the government on the capabilities and limitations of all aspects of verification in the course of nuclear disarmament. A national R&D programme could have the dual purpose of carrying out new research in the field (including making practical preparations for disarming) and of providing a general education to UK scientists and officials in the field of verification.

The fact that the US verification programme is many times bigger than the UK's (and possibly any other country's) would ever become should not dissuade the UK

77 Personal communication from David J. Simons, Program Manager, Research and Development, Nonproliferation and International Security Division, Los Alamos National Laboratory, New Mexico, US.

(or any other country) from becoming involved in the field. Aside from the need for indigenous expertise, it is not only the amount of resources applied to a problem that is important. The quantity of chemical and biological disarmament research undertaken in the US is several times greater than that carried out in the UK, yet the UK has made leading contributions to this field, as have other countries including Australia, Germany, Sweden and the Netherlands. Similarly, a small research team at AWE Blacknest, working on forensic seismology, has for 40 years carried out valuable independent research, whose results have added considerably to those produced by far larger US programmes.[78]

There is then ample scope for a nuclear arms control and disarmament research programme in Britain, in each of the other nuclear weapon states, and possibly in several other nations too. A verification programme in the UK employing 100 scientists and engineers, and costing 10 to 20 million pounds, could be envisaged as a start.[79] As in other matters of national security, it would be prudent to invest in a wide range of promising work, at least initially, rather than to risk overlooking an important line of technical development. Indeed, a British programme could easily grow larger than this, should prototype equipment or facilities be constructed, major national studies be commissioned (say on material disposition, or the dismantlement of Trident warheads), or co-operative programmes with Russia and other former Soviet states take hold.

The focus of such a programme in the UK should be at AWE Aldermaston, just as comparable programmes established by any other nuclear weapon state would likely be based at its national nuclear weapons facilities. Although several other UK bodies have relevant expertise and would play a part in the UK's work in this field, AWE scientists have the skills and security clearances necessary to deal with sensitive issues; and the knowledge of the details and the characteristic signatures of nuclear processes. AWE also provides access to the weapon components and facilities needed when developing verification technologies and techniques.[80]

Were nuclear disarmament to become a serious objective of major nations and research efforts receive greatly increased funding, then perhaps verification research

78 See Milne and Wilson, pp. 46-51.

79 For a more detailed analysis, and justification of these numbers see Milne and Wilson.

80 Milne and Wilson.

could, in due course, be spread through the scientific and technological base, as is now the case with military R&D. University chemistry departments could be involved in environmental sampling techniques for verification; geology and geophysics departments could contribute to forensic seismological research; major industrial companies, with R&D laboratories of their own, could become involved.

An ambitious project for the UK would be to establish a national centre of excellence on verification in support of nuclear disarmament. Such a verification centre could well be associated with Aldermaston, in order to make the best use of this concentration of nuclear weapons expertise (it could be housed in buildings on the Aldermaston site outside the wire), but it might be an independent body, carrying out entirely unclassified work and breaking away from the culture of secrecy that dominates a weapons establishment.[81]

To sum up, although a national 'verification laboratory' in Britain may not now be in prospect, engaging a hundred or so of AWE's scientific and technical workers on verification work could be accomplished quickly and easily, given political backing. A national verification programme might in time grow to double or even several times this size. If this could be replicated in, say, ten or twenty countries, it might engage thousands of additional scientists and technologists, with a broad range of perspectives and experience, in the quest for nuclear disarmament.

Such an order-of-magnitude increase in verification research, spread among several countries, would be likely to improve the attainable standard of technological verification, facilitate international agreement on particular technologies and techniques for use in disarmament treaties, and serve a general confidence-building function likely to promote progress in international nuclear disarmament.

Specific Opportunities and Challenges for Improving Technological Verification Capabilities

To try to indicate some of the specific ways in which technical verification capabilities could improve over the coming years, we discuss a few of the most promising and challenging areas of current research.

81 For a more detailed discussion see Milne and Wilson.

One crucial verification task, already discussed in this report, is verification of the dismantlement of warheads. Although the basic technologies for verifying warhead dismantlement are mostly understood, international agreement needs to be reached on particular verification techniques and protocols. Techniques for warhead authentication need to be 'red-teamed' (trials in which one group of scientists play inspectors and another group represent the inspected party) and demonstrated internationally. Chain-of-custody techniques, perimeter portal monitoring equipment, tags, seals, remote monitoring equipment—all need to be refined. The appropriate standards are high. Tags and seals need to be sufficiently sophisticated that they cannot be tampered with by a government agency using national technical resources. Systems of monitoring and physical containment must ensure that national agencies are unable to remove sequestered equipment or materials undetected.

A second area where technical improvements can be made is in IAEA safeguards on the nuclear fuel cycle. Mainstream advances in artificial intelligence and communications technology, and in consumer electronics such as video cameras and personal computers, are making it possible to design improved technology for verification. Such new technology could be used, in theory, both to make safeguards more effective and to reduce their cost. What is needed is an objective analysis of the benefits, disadvantages and costs of deploying technological aids to nuclear safeguards.[82]

A third area of technological development, which again can be used by the IAEA, is the application of environmental monitoring to detecting clandestine nuclear activities.[83] Small quantities of nuclear materials are lost during manufacturing processes no matter what precautions are taken to prevent this happening. If these nuclear materials can be detected, they may identify specific nuclear processes. A US Office of Technology Assessment (OTA) report published in 1995[84] concluded that the use of environmental monitoring can 'significantly increase the ability of

82 Garwin.

83 Article 6. b. of the Model Additional Protocol to NPT safeguards agreements, approved by the Board of the IAEA in 1997 for implementing the 93+2 recommendations, states that the Agency may carry out: '. . . the collection of environmental samples; and other objective measures which have been demonstrated to be technically feasible . . .'

safeguards to detect undeclared nuclear activities at declared sites',[85] and that '[t]echnologies under development can significantly increase the chances of detecting and locating undeclared sites.'[86]

A fourth area of research is the means for obtaining independent confirmation of declarations of fissile material production, warhead inventories, and prior dismantlement of warheads. The US Department of Energy is funding research on global stockpiles of fissile materials, including the fundamental problems facing attempts to establish comprehensive histories of nuclear programmes and comprehensive inventories of nuclear materials. The UK's 1998 Strategic Defence Review promised increased transparency about UK military fissile material stockpiles, including historical accounting of fissile material production since the start of Britain's nuclear defence programme in the 1940s. There is obvious scope for collaboration among the nuclear weapon states on methodology, data collection. Any such work might prove a useful adjunct to official negotiations on a fissile material cut-off treaty.

Fifth, and last, new approaches can be sought to try to ameliorate a real disaster for verification, the 'bomb in the basement' problem. The US has carried out a great deal of research on the potential for truly revolutionary for detecting clandestine nuclear activities and weaponry. There is, for example, a Nuclear Emergency Search Team (NEST) project, based at Los Alamos, working on this sort of scenario. There is no breakthrough in sight, although nations will continue to work towards lowering technical detection thresholds.

84 *Environmental Monitoring for Nuclear Safeguards*, US Congress, OTA, OTA-BP-ISS-168, Government Printing Office, Washington D.C, Sept. 1995.

85 There are obvious reasons for any country wishing to secretly develop nuclear weapons to locate weapons activities at the same site as civilian activities. Prominent staff, who would be missed should they disappear from public life, can work on both programmes without arousing suspicion; facilities, suppliers and security arrangements can be shared; and so on. Iraq co-located some of its declared civilian and undeclared military activities. The IAEA believes that had it employed environmental moniyoting in the 1980s it would have detected Iraq's nuclear programme.

86 *Environmental Monitoring for Nuclear Safeguards*, p. 2. The remote detection of trace chemicals in the environment is a major programme at The US DoE. One major initiative, for example, is the CALIOPE programme (Chemical Analysis by Laser Interrogation of Proliferation Effluents), which is developing technologies for remote identification of chemicals using laser-based sensing methods.

4. Conclusion

In considering the verification requirements for disarmament from low levels of nuclear weapons to a nuclear weapon-free world this report has envisioned a stage of disarmament perhaps 20 years hence. The aim was not to write a manual for future decision-makers, but to produce a document rich in references and ideas that could serve as inspiration now for further study of this important area. A basic premise is that the possibilities for disarmament and verification will have changed significantly in the intervening time, not least by the process of disarming to low levels. A second premise is that verification is not the be-all and end-all of nuclear disarmament, and that technical solutions are not the be-all and end-all of verification. Both demand effective political solutions.

As the second in the series of four studies that comprise VERTIC's 'Getting to Zero' project, the report takes as its starting point the work of Patricia Lewis, who in the first of the series, entitled *Laying the Foundations for Getting to Zero: Verifying the Transition to Low Levels of Nuclear Weapons*, outlines a possible scheme for verifying disarmament from the current numbers of nuclear weapons down to low levels.

The current report attempts to identify trends that will affect the future possibilities for verifying nuclear disarmament. One factor certain to influence such possibilities is the availability of effective technologies. There already exists a considerable understanding of many of the basic verification processes needed to support disarming to zero nuclear weapons. Although it will be important to improve the existing technologies, it is anticipated that there is scope only for incremental rather than revolutionary developments. What is most needed now, from the point of view of promoting disarmament, is a global effort to increase the practical understanding and effective application of existing verification technologies and techniques.

This thought leads to consideration of a second factor identified in the report as likely to affect the future possibilities for verification, that is, global patterns of verification research and development. At the moment the US is doing the overwhelming bulk of the work in this area. The report recommends strongly that states other than the US should research verification tasks and techniques ahead of future disarmament needs. The benefits of doing so are twofold. First, in performing such R&D, states can work out for themselves the practicalities and limitations of existing techniques, which will build confidence in the techniques, itself a prerequisite for disarmament. Second, an expansion in the global verification R&D effort to include states other than the US would, with the sharing of results, bring added creativity and new perspectives to the development of verification technology and techniques. Although the US has a large verification programme, there is much for other nations to contribute.

A third factor that could affect the future scope for nuclear disarmament and verification is the increasing openness between nations. This can be seen in the acceptance by states of more intrusive arms control measures for example, on-site inspections, that were unthinkable in the 1960s. Not that there is always a linear increase in prospects for verification and disarmament; a disarmament process can experience a 'backlash', whereby verification objectives are lowered and arms control arrangements consequently weakened. Openness in nuclear weapons establishments is especially important. Because of this, the report recommends that when setting up verification R&D programmes, states make international collaboration an integral part of their operation.

To reiterate, states other than the US should set up verification R&D programmes and these should incorporate international collaboration. The possibility of nuclear disarmament and effective verification of a nuclear weapon-free will would increase if more states do more verification work more openly.

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About VERTIC

VERTIC, the Verification Research, Training and Information Centre, was established in 1986 as the Verification Technology Information Centre. It is an independent, non-profit, non-governmental organisation. Its mission is to promote effective and efficient verification as a means of ensuring confidence in the implementation of treaties or other agreements which have international or national security implications. Along with verification, VERTIC also concerns itself with the negotiation, monitoring and implementation of such agreements and the establishment of confidence-building measures to bolster them.

VERTIC aims to achieve its mission by means of:

- research
- training
- dissemination of information, and
- interaction with the relevant political, diplomatic, technical, scientific and non-governmental communities.

VERTIC's 'clients' are policy-makers, the media, legislators, academics, students and others needing reliable information on and analysis of verification and monitoring issues.

What are VERTIC's research priorities?

While maintaining a watching brief on all aspects of verification and related issues, VERTIC specialises in the following three broad areas.

Peace and Security, including verification and monitoring of international and intra-national peace accords by means of peacekeeping operations and their strengthening through civilian confidence-building measures.

VERTIC's current projects in this area include verification of the decommissioning of weapons in Northern Ireland and the Kosovo Verification Mission.

Arms Control and Disarmament, including the verification of international conventions on nuclear non-proliferation, nuclear disarmament, nuclear testing, chemical and biological weapons and conventional weapons.

VERTIC's current projects in this area are on:

- the implementation and verification of the Comprehensive Test Ban Treaty (CTBT)
- verification of the transition to a nuclear weapon-free world ('Getting to Zero')

- verification of the Landmine Ban Treaty (Ottawa Convention).

The Environment.

VERTIC's current project in this area is on the implementation and verification of the Climate Change Convention and its Kyoto Protocol.

How does VERTIC operate?

VERTIC is based in central London, governed by a Board of Directors and advised by an International Verification Consultants Network.

VERTIC is mostly funded by philanthropic trusts and foundations, currently the Ford Foundation, the John Merck Fund, the Ploughshares Fund, the Rockefeller Family Philanthropic Offices, the Joseph Rowntree Charitable Trust, the John D. and Catherine T. MacArthur Foundation and the W. Alton Jones Foundation. VERTIC also accepts commissions from governments and other organisations.

What are VERTIC's activities?

VERTIC holds its own seminars, workshops and conferences and participates in those organised by other organisations worldwide.

VERTIC's staff publish widely in the general and specialist press, academic journals and books.

VERTIC has its own publications: a newsletter, *Trust & Verify;* a *Verification Yearbook*; a *Verification Organisations Directory*; and *VERTIC Research Reports* and *Briefing Papers*.

VERTIC is often the first port of call for media representatives seeking information on and analysis of verification issues.

VERTIC also has an intern programme.

VERTIC cooperates closely with United Nations bodies, other international organisations, universities, research centres, governments and non-governmental organisations. It has consultative (roster) status with the UN's Economic and Social Council (ECOSOC).

What are VERTIC's publications?

Trust and Verify
Published six times a year, providing analysis and news of verification developments and information on VERTIC's activities. Annual subscriptions for a paper copy are £15 (individual) or £25 (organisation). *Trust & Verify* can also be received via email on request. Each issue may be found at VERTIC's website shortly after publication.

Verification Yearbook
Beginning with 1991, each edition surveys the preceding year's developments in verification and related areas; identifies problems still in need of solution; and draws attention to under-explored possibilities. The 1997 *Yearbook* and copies of most previous editions are available from VERTIC. VERTIC is currently planning a Year 2000 Yearbook.

VERTIC Research Reports and Briefing Papers
These are published on an *ad hoc* basis and cover a range of verification issues.

Verification Organisations Directory
VERTIC annually publishes a directory of all organisations involved in verifying or monitoring arms control and disarmament agreements or which conduct research into verification and monitoring. International, regional, national and non-governmental organisations will be included. The inaugural 1999 edition is now available.

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