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TRANSPARENCY IN NUCLEAR WARHEADS AND MATERIALS

THE POLITICAL AND TECHNICAL DIMENSIONS

EDITED BY
NICHOLAS ZARIMPAS

At a time when arms control is being deconstructed by some and a blueprint for its reconstitution is being sought by others, the enhancement of transparency in nuclear warheads and materials as a means to achieve deeper and irreversible nuclear reductions deserves urgent attention. The contributions in this volume map out the progress made and identify and discuss the reasons why countries possessing nuclear weapons are impeding transparency. The main focus is on the technical means and procedures that have been used, are under development or have been proposed for building, strengthening and institutionalizing transparency. The authors analyse the arrangements for the establishment of stockpile declarations, the verification of nuclear warhead status and dismantlement, the storage and disposal of fissile materials, as well as the monitoring of production facilities.

This volume brings together a unique and wide body of information and in-depth analysis by an informed group of arms control experts and is expected to stimulate international debate on the subject of nuclear transparency.

Dr Nicholas Zarimpas (Greece) was Leader of the SIPRI Project on Military Technology and International Security in 1999–2002. He previously worked for the European Commission and the Organisation for Economic Co-operation and Development, where he specialized in the nuclear fuel cycle and the management of plutonium. During the past 10 years he has acted as scientific secretary to several international technological and policy committees.

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The Political and Technical Dimensions

Stockholm International Peace Research Institute

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Preface

Since 11 September 2001, security issues have been propelled back to the top of the international agenda, and nuclear issues with them. Concern about transnational, mass-impact terrorism makes it imperative to do everything possible to stop nuclear, biological and chemical weapons getting into the hands of terrorists—criminals or other irresponsible people or groups. The possible nuclear capabilities of states like Iraq and North Korea have become a focus of both debate and action, because of their potential contribution to further proliferation but also because of these states' record of regional confrontation. Relations between India and Pakistan have gone through periods of extreme tension, when actual hostilities seemed only a step away and the risk of escalation to a nuclear exchange could not be ruled out.

This book contains the fruits of a major cooperative research project coordinated by Nicholas Zarimpas at SIPRI, and supported by the John D. and Catherine T. MacArthur Foundation, in 1999–2002.

The contributors were asked to focus on the inherent importance, the track record and the future relevance of transparency as a concept applied to nuclear warheads and materials. Although some of them take different views on what should be classified as measures of transparency, all of them see the idea itself as desirable both for general security purposes and in the context of identifying and stopping risks of nuclear proliferation. They do, however, acknowledge and explore the contradictions between further advances in transparency and the other perceived goals and interests of the recognized nuclear weapon states. They are not sanguine about applying the concept to other known and suspected weapon possessors, even if the nuclear weapon states were to set a good example. In these most difficult cases the international community has found itself with few options in real life except those inherently risky options of containment or a coercive approach to disclosure and destruction.

The first merit of this book is that it brings together a body of information not assembled before, with contributors *inter alia* from all five nuclear weapon states. Its second merit will be, I hope, to stimulate informed debate at a time when arms control is being deconstructed by some and a blueprint for its reconstruction is being sought by others. Nicholas Zarimpas' own contributions raise the question of whether arms control can go forward without transparency in some instances, and transparency without arms control in others. Such flexibility, mixed with the conviction that progress must be made on this challenge one way or another, is a prescription worth pondering for the future.

Alyson J. K. Bailes
Director of SIPRI
December 2002

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An Advisory Committee consisting of Thérèse Delpech, Steve Fetter and Alexander Pikayev established the general framework of the project, outlined its research objectives and identified contributors. Thérèse Delpech provided invaluable support in organizing an authors' workshop in February 2000. Frank von Hippel's suggestions helped to ensure the right membership of the team. Oleg Bukharin graciously shared his knowledge and time and carefully reviewed all the chapters in the technical part of the book.

All the material presented and discusssed by the authors is based on open, published sources. They contributed in their personal capacities, as experts in their fields.

Shannon N. Kile, SIPRI project researcher, assisted during the initial phase of the project, as well as with the final editing of the book after I had left SIPRI. The staff of the SIPRI Editorial Department applied their exceptional skills and worked long hours to edit the manuscripts. I am very grateful to Pamela Boston, Andy Mash, Teslin Seale and Connie Wall. I also acknowledge the expert help of Gerd Hagmeyer-Gaverus and Duchesne Stanbridge in the production of the diagrams. The index was prepared by Peter Rea, UK.

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Nicholas Zarimpas
SIPRI Project Leader
July 2002

Acronyms and abbreviations

ABM	Anti-ballistic missile
ALCM	Air-launched cruise missile
AMS/IB	Attribute measurement system with an information barrier
ARIES	Advanced recovery and integrated extraction system
AVLIS	Atomic vapour laser isotope separation
BTWC	Biological and Toxin Weapons Convention
CBM	Confidence-building measure
CD	Conference on Disarmament
CFE	Conventional Armed Forces in Europe (Treaty)
CIVET	Controlled intrusiveness verification technology
C&S	Containment and surveillance
CSA	Canned secondary sub-assembly
CTBT	Comprehensive Nuclear Test-Ban Treaty
CTBTO	Comprehensive Nuclear Test-Ban Treaty Organization
CTR	Cooperative Threat Reduction
CWC	Chemical Weapons Convention
DAF	Device assembly facility
DES	Digital encryption standard
DNLEU	Depleted, natural, low-enriched uranium
DOD	Department of Defence
DOE	Department of Energy
EMIS	Electromagnetic isotope separation
EU	European Union
Euratom	European Atomic Energy Community
FMCT	Fissile Material Cut-off Treaty
FMSF	Fissile materials storage facility
FMTTD	Fissile materials transparency technology demonstration
FSU	Former Soviet Union
FY	Fiscal year
GPS	Global positioning system
HE	High explosive
HEU	Highly enriched uranium
HMX	High-melting explosives
HPGe	High-purity germanium detector
HRGS	High-resolution gamma-ray spectrometry
IAEA	International Atomic Energy Agency
IB	Information barrier

ICBM	Intercontinental ballistic missile
INF	Intermediate-range nuclear forces
IPP	Initiatives for Proliferation Prevention
keV	Kilo-electronvolt
kg	Kilogram
km	Kilometre
LANL	Los Alamos National Laboratory
LEU	Low-enriched uranium
LIDAR	Laser-imaging detection and ranging
LWR	Light-water reactor
LLNL	Lawrence Livermore National Laboratory
MeV	Mega-electronvolt
Minatom	Ministry of Atomic Energy
MIRV	Multiple independently targetable re-entry vehicle
MOD	Ministry of Defence
MOX	Mixed oxide (fuel)
MPC&A	Materials protection, control and accounting
MCA	Multi-channel analyser
MSR	Multiplicity shift register
MTCR	Missile Technology Control Regime
NATO	North Atlantic Treaty Organization
NEM	Nuclear explosive materials
NEP	Nuclear explosive package
NCI	Nuclear Cities Initiative
NDA	Non-destructive assay
NHP	Nuclear History Programme
NGO	Non-governmental organization
NMC	Neutron multiplicity counter
NMD	National missile defence
NMIS	Nuclear materials identification system
NNWS	Non-nuclear weapon state
NPT	Non-Proliferation Treaty
NSA	Negative security assurances
NSG	Nuclear Suppliers Group
NTM	National technical means
NWIS	Nuclear weapons identification system
NWFZ	Nuclear weapon-free zone
NWS	Nuclear weapon state
PDCF	Pit disassembly and conversion facility
PINS	Portable isotope neutron spectroscopy
PMDA	Plutonium Management and Disposition Agreement
PNI	Presidential Nuclear Initiatives

PNNL	Pacific Northwest National Laboratory
PPCM	Perimeter-Portal Continuous Monitoring
PPIA	Processing and Packaging Implementation Agreement
PPRA	Plutonium Production Reactor Agreement
PSA	Positive security assurances
PTBT	Partial Test Ban Treaty
PUREX	Plutonium and uranium recovery by extraction
R&D	Research and development
RIS	Radiation identification system
RMA	Revolution in Military Affairs
RPT	Reflective particle tag
RV	Re-entry vehicle
SALT	Strategic Arms Limitation Talks/Treaty
SHA	Secure hash algorithm
SLBM	Submarine-launched ballistic missile
SLCM	Sea-launched cruise missile
SNDV	Strategic nuclear delivery vehicle
SNL	Sandia National Laboratories
SORT	Strategic Offensive Reductions Treaty
SSBN	Nuclear-powered, ballistic missile submarine
SST	Safe-secure trailer
START	Strategic Arms Reduction Treaty
SWU	Separative work unit
TID	Tamper-indicating device
TLI	Treaty-limited item
TMS/IB	Template measurement system with an information barrier
TRIS	Trusted radiation inspection system
UIT	Ultrasonic intrinsic tag
UN	United Nations
UNSCOM	UN Special Commission on Iraq
UNMOVIC	UN Monitoring, Verification and Inspection Commission

1. Introduction

Nicholas Zarimpas

I. Towards nuclear disarmament?

With the end of the cold war and the successful implementation of nuclear arms control treaties, the risk of a large-scale nuclear confrontation has been drastically reduced. A number of bilateral, regional and multilateral agreements—from the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (Partial Test Ban Treaty, PTBT) to the 1987 Soviet/Russian–US Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty) and the 1991 Russian–US Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty)—have curbed and effectively stabilized the nuclear arms race. Several countries have abandoned their nuclear weapon ambitions, nuclear arsenals have been reduced by about half, nuclear weapon deployment has been excluded from large geographical regions, and international norms against nuclear weapon proliferation and testing have been established.[1]

The most dramatic reductions in nuclear arms occurred in the 1990s, although competing tendencies could also be discerned. The euphoria that prevailed in the early part of the decade was absent during the second half. Although the aggregate number of nuclear weapons continued to decline slowly but steadily, the prospects for further successes in nuclear arms control diminished, as exemplified by the stagnation of the START process, the US Senate's decision in 1999 not to ratify the 1996 Comprehensive Nuclear Test-Ban Treaty (CTBT) and the inability of the Conference on Disarmament (CD) to proceed with substantive work on nuclear issues. India, Israel and Pakistan continued to remain outside the framework of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), largely because of regional rivalries, and India and Pakistan conducted nuclear tests in 1998. The first wave of the enlargement of NATO, in 1997, and the NATO intervention in Yugoslavia in 1999 led to the further deterioration of Russian–US relations and resulted in a near-halt to their bilateral security dialogue. There was also growing tension on many fronts between China and the United States.

Opposing perceptions of the nature of the threat posed by the proliferation of long-range ballistic missiles capable of carrying non-conventional weapons have caused additional strain in the relations between Russia and the USA. The December 2001 decision of the USA to withdraw unilaterally from the 1972

[1] United Nations, *United Nations Disarmament Yearbook*, vol. 24: 1999 (UN: New York, 2000), p. viii.

Treaty on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty), effective as of 13 June 2002, in order to pursue an unproven missile defence technology may also have destabilizing implications. Several countries, notably China and Russia, may feel compelled to develop new missiles with improved capabilities and sophisticated countermeasures, further increasing global and regional tensions.[2] In the years to come, the deployment of missile defences will shape world strategic and military balances and thus directly influence the course of arms control and disarmament.

Despite the likelihood that there will be a turn away from arms control and a drift towards unilateral action, a distinct feature of recent years has been the continued Russian–US cooperation in efforts to strengthen the safety and security of nuclear warheads and materials and to promote transparency. The principal aim of the programmes has been to address the proliferation threats posed by the break-up of the Soviet Union. The most noteworthy bilateral initiatives are the unprecedented commercial deal to down-blend and transfer to the USA hundreds of tonnes of highly enriched uranium (HEU) from dismantled Russian warheads, the agreement to dispose of large quantities of weapon-grade plutonium, and the sustained efforts to prevent the theft, ensure the security and halt the further production of fissile material for military purposes in Russia. International projects funded by the European Union, Japan, the USA and other countries have aimed to engage Russian and other nuclear weapon scientists from the former Soviet Union in non-military activities. Other initiatives include plans for downsizing and consolidating Russia's nuclear weapon complex and for building a storage facility for surplus Russian plutonium and HEU.

Russia and the USA have continued to make progress in reducing their nuclear arsenals. The paramount achievements in nuclear reductions include the successful implementation of the INF and START I treaties and the substantial body of accumulated technical, legal and organizational experience gained from it. More recently, and in spite of the negative expectations at the start of this decade, in May 2002 Russia and the USA signed the Strategic Offensive Reductions Treaty.[3]

China, France and the United Kingdom have not been involved in multilateral arms control, primarily because of the relatively small size of their nuclear assets compared with those of Russia and the USA. However, in the late 1990s, both France and the UK proceeded to make substantial unilateral reductions in their nuclear weapon arsenals and to close and dismantle nuclear material production and weapon testing facilities. In addition, the UK, like the USA, took serious steps towards increasing transparency in its nuclear holdings.

[2] Biden, J. R., 'Missile defense delusion', *Washington Post*, 19 Dec. 2001, p. A39; and Lewis, G., Gronlund, L. and Wright, D., 'National missile defense: an indefensible system', eds J. Cirincione *et al.*, *Nuclear Tensions in a New Era* (Carnegie Endowment for International Peace: Washington, DC, 2000), pp. 32–33.

[3] The full text of the Strategic Offensive Reductions Treaty (SORT) is available at URL <http://www.fas.org/nuke/control/sort/sort.htm>. The treaty will enter into force when it has been ratified by both signatories. For evaluations of SORT see chapters 2 and 4 in this volume.

After the indefinite extension of the NPT in 1995, the nuclear weapon states (NWS) joined in an 'unequivocal undertaking to accomplish the total elimination of their nuclear arsenals leading to nuclear disarmament' at the May 2000 NPT Review Conference.[4] This was a fresh commitment to their obligation under Article VI of the treaty 'to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament'.[5] However, since a specific time frame was not agreed and the NWS have made little progress towards achieving the aims of the 1995 NPT Review and Extension Conference, a speedy move beyond statements of intent is anything but assured. Arms control and the eventual elimination of nuclear weapons can only be advanced within a stable and well-functioning global non-proliferation regime. While the overwhelming majority of the non-nuclear weapon states (NNWS) parties to the NPT, with the exception of Iraq and North Korea, have over the years honoured the letter and the spirit of the treaty and demonstrated full compliance with their International Atomic Energy Agency (IAEA) safeguards agreements, the continued support of the NNWS for the NPT regime will depend on tangible actions leading to disarmament being taken by the NWS.

In marked contrast to the deadlock in arms control, a serious, intense and stimulating debate about the complete elimination of nuclear weapons has been under way since the mid-1990s. Governments, international commissions and influential individuals have made concerted efforts to address the possibility of a world free of nuclear weapons and have put forth concrete proposals for measures to achieve this goal. A few deserve special mention. The Canberra Commission on the Elimination of Nuclear Weapons, established in 1995 by the Australian Government, issued a report which concluded: 'The end of the Cold War has created a new climate for international action to eliminate nuclear weapons, a new opportunity'.[6] After the 1998 Indian and Pakistani nuclear tests, the Japanese Government convened the Tokyo Forum for Nuclear Nonproliferation and Disarmament. The forum stated in a set of recommendations in 1999 that the NWS should eliminate nuclear weapons through phased reductions.[7] Such calls were eloquently echoed in statements by former senior military officers and civilian leaders from many countries.[8]

[4] Final Document of the 2000 Review Conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2000/28, 24 May 2000, available at URL <http://www.iaea.org/worldatom/Press/Events/Npt/npt-2000.shtml>.

[5] The text of the NPT is available at URL <http://www.iaea.org/worldatom/Documents/Legal/npttext.shtml>.

[6] *Report of the Canberra Commission on the Elimination of Nuclear Weapons* (Australian Ministry of Foreign Affairs and Trade: Barton, Aug. 1996), p. 10, available at URL <http://www.dfat.gov.au/cc/cchome.html>.

[7] Tokyo Forum for Nuclear Non-Proliferation and Disarmament, *Facing Nuclear Dangers: An Action Plan for the 21st Century* (Ministry of Foreign Affairs of Japan: Tokyo, 25 July 1999), available at URL <http://www.fas.org/news/japan/forum.htm>.

[8] E.g., 'Statement on nuclear weapons by international generals and admirals', 5 Dec. 1996, URL <http://www.nuclearfiles.org/docs/1996/961205-admirals.html>; and Green, R. D., *Fast Track to Zero Nuclear Weapons*: *The Middle Powers Initiative* (Middle Powers Initiative: Cambridge, Mass., 1999), pp. 47–48, available at URL <http://www.stopthebombs.org/nuke/middle-powers.pdf>.

Although the NWS have raised political objections and substantial obstacles to initiatives for the abolition of nuclear weapons, international support has been growing. The New Agenda Coalition (NAC), launched in 1998 by eight countries sharing the objective of a world free of nuclear weapons, stated in its declaration: 'The international community must not enter the third millennium with the prospect that the maintenance of these weapons will be considered legitimate for the indefinite future, when the present juncture provides a unique opportunity to eradicate and prohibit them for all time'.[9]

Initiatives of this kind, although important for generating public support and legitimizing the goal of the abolition of nuclear weapons, have had little immediate impact on the deeply embedded nuclear policies of the NWS. Alarmingly, the prominence of nuclear weapons, including their potential first use, has been reinforced in recent years in the military doctrines and perceptions of most NWS as well as by NATO.[10] Russia and the USA continue to deploy thousands of strategic nuclear weapons on a state of high alert and at enormous expense.[11] Nuclear war planning in Russia and the USA continues to be similar in many respects to their planning during the cold war.[12] China, France and the UK also appear to be committed to retaining their nuclear forces indefinitely.[13] Tactical nuclear weapons, a difficult issue, remain outside arms control regimes. They rank low on the political agenda, and significant uncertainties exist about their numbers and deployment.

In summary, events during the past decade have demonstrated a mix of successes, setbacks, delays and uncertainties. There are clear and worrying signs that the web of instruments for furthering arms control and disarmament will face increasingly difficult challenges. As recent trends have indicated, the prospects for the complete elimination of nuclear weapons in the short term are not good. Favourable circumstances for cooperation between the NWS, such as those that emerged after the terrorist attacks against the United States on 11 September 2001, may nevertheless arise again, allowing them to pursue deeper nuclear reductions. Some of the prerequisites for achieving deeper cuts are the improvement of relations between the dominant powers, the resolution of armed conflicts, enlightened leadership, political will, the preservation of arms control accomplishments and the sustainment of efforts to counter nuclear proliferation.

[9] Joint Declaration by the Ministers for Foreign Affairs of Brazil, Egypt, Ireland, Mexico, New Zealand, Slovenia, South Africa and Sweden, Conference on Disarmament document CD/1542, 11 June 1998, available on the Acronym Institute Internet site at URL <http://www.acronym.org.uk/27state.htm>. Slovenia later withdrew from the NAC.

[10] China is the only NWS to have made a no-use pledge with regard to the NNWS and a no-first-use pledge with regard to the other NWS.

[11] Butler, L., 'Zero tolerance', *Bulletin of the Atomic Scientists*, vol. 56, no. 1 (Jan./Feb. 2000), p. 72.

[12] Younger, S. M., *Nuclear Weapons in the Twenty-first Century*, LA-UR-00-2850 (Los Alamos National Laboratory: Los Alamos, N. Mex., 27 June 2000), p. 2.

[13] Rogers, P., Memorandum submitted to the Foreign Affairs Committee, Weapons of Mass Destruction, Eighth Report, House of Commons, Session 1999–2000, 25 July 2000, pp. 1–12. See also United Nations (note 1).

II. Nuclear warheads and fissile materials

The NPT-recognized NWS—China, France, Russia, the UK and the USA—possess sophisticated nuclear weapons.[14] Three other states have nuclear capabilities: India and Pakistan conducted nuclear explosions in 1998, and Israel is widely believed to possess nuclear weapons.

It has been estimated that about 128 000 warheads were built between 1945 and 2000.[15] In 1986, the world nuclear stockpile peaked at close to 70 000 warheads. According to published estimates, in 2001 about 17 150 nuclear warheads were deployed by these eight states. If all nuclear warheads are counted—including non-deployed spares, those in both active and inactive storage, and 'pits' (plutonium cores) held in reserve—the total world stockpile consisted of about 36 800 warheads in early 2002.[16] Approximately 97 per cent of these warheads were in the Russian and US arsenals, and a significant fraction of them, several thousand, were warheads for tactical nuclear weapons.[17] It is not known how many warheads India, Israel and Pakistan possess.

The downward trend in the number of nuclear warheads is likely to continue as Russia and the USA further reduce their stockpiles. However, both countries plan to retain large reserve inventories of intact warheads and warhead components. It has been suggested that Russia will not be in a position to maintain more than 1500 warheads by 2010 because of the technical obsolescence of its systems and because of its financial situation.[18]

There are no official statistics on the exact total numbers, categories and types of warhead in the inventories of the NWS.[19] The NWS are not legally obliged to declare the production or destruction of their warheads or to submit them to any kind of control. Moreover, bilateral agreements, such as the INF and START I treaties, do not specifically require the elimination of warheads after they have been removed from their delivery platforms. Nevertheless, following the implementation of these treaties and unilateral pledges, thousands of redundant and technically obsolete warheads have been dismantled. In the

[14] Existing bilateral arms control treaties and agreements, as well as multilateral treaties of global application such as the NPT and the CTBT, do not provide definitions of the terms 'nuclear warhead' or 'nuclear weapon'. A nuclear warhead can be defined as a mass-produced, reliable, predictable nuclear device capable of being carried by missiles, aircraft or other means. A nuclear weapon is a nuclear warhead mated and fully integrated with a delivery platform. Cochran, T. B., Arkin, W. M. and Hoenig, M. M., *Nuclear Weapons Databook, vol. I: US Nuclear Forces and Capabilities* (Ballinger: Cambridge, Mass., 1984), p. 2.

[15] Norris, R. S. and Arkin, W. M., 'Global nuclear stockpiles, 1945–2000', *Bulletin of the Atomic Scientists*, vol. 56, no. 2 (Mar./Apr. 2000), p. 79, available at URL <http://www.thebulletin.org/issues/nukenotes/ma00nukenote.html>.

[16] Kristensen, H. and Handler, J., 'World nuclear forces', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), p. 525. It should be noted that significant uncertainties are associated with such estimates.

[17] See, e.g., Potter, W. C. *et al.* (eds), *Tactical Nuclear Weapons: Options for Control*, UNIDIR 2000/20 (United Nations Institute for Disarmament Research (UNIDIR): Geneva, Dec. 2000).

[18] 'Putin to cut nuclear spending', *New York Times*, 13 Aug. 2000.

[19] The 5 parties to the START I Treaty—Belarus, Kazakhstan, Russia, Ukraine and the USA—exchange data, semi-annually, on their deployed treaty-accountable strategic nuclear warheads. The UK has announced that it has fewer than 200 operationally available warheads.

USA alone, almost 12 000 warheads have been eliminated since 1990 and there are plans to finish disassembling the current backlog of retired warheads by the end of 2005.[20] The former Soviet Union reportedly began dismantling its warheads in the mid-1980s, after it began to consolidate its weapons complex; some sources claim that Russia is dismantling about 2000 warheads each year.[21]

Starting in the 1940s, countries with military nuclear programmes produced vast quantities of fissile material.[22] A total of about 242–267 tonnes of weapon-grade plutonium is held in operational, reserve or retired warheads, warhead components, solutions and scrap or waste material.[23] The aggregate military HEU inventory is about 1700 tonnes (not including submarine fuel or waste). Most of this material is believed to be held outside nuclear warheads, varying, for example, between 75 per cent for the Russian stockpile and 65 per cent for the US stockpile. As in the case of warheads, Russia and the USA possess the largest stockpiles of fissile material, exceeding by at least one order of magnitude the combined stockpiles of the other three NWS. Both countries have designated hundreds of tonnes of fissile material as excess to their military needs and have agreed to dispose of some of it.[24] The UK has also declared a quantity of military plutonium as excess material.

With the exception of China, the NWS have officially declared moratoria on the production of plutonium and HEU. However, it is believed that none of them produces fissile material for weapon purposes.[25] This is not likely to be the case for India, Israel or Pakistan. The USA has released detailed information on its past production and use and its current holdings of weapon-grade plutonium.[26] A similar exercise, but of a more limited scope, was conducted in the UK.[27] In addition, the USA has published figures on its total production of HEU.[28]

[20] Statement of Brigadier General Thomas F. Gioconda, US Air Force, Acting Deputy Administrator for Defense Programs, National Nuclear Security Administration, US Department of Energy, to the Fiscal Year 2001 Appropriations Subcommittee, p. 6.

[21] E.g., Woolf, A. F., *Nuclear Weapons in Russia: Safety, Security, and Control Issues*, CRS Issue Brief for Congress, IB98038 (Congressional Research Service: Washington, DC, 21 Nov. 2000).

[22] The main fissile materials used in nuclear weapons are the isotopes plutonium-239 and uranium-235. Highly enriched uranium is uranium containing over 20% uranium-235. See chapter 7 in this volume. For a detailed discussion see Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997).

[23] Norris, R. S. and Arkin, W. M., 'World plutonium inventories, 1999', Natural Resources Defense Council (NRDC), 'Nuclear Notebook', *Bulletin of the Atomic Scientists*, vol. 55, no. 5 (Sep./Oct. 1999), p. 71, available at URL <http://www.bullatomsci.org/issues/nukenotes/so99nukenote.html>.

[24] Bunn, M., *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Carnegie Endowment for International Peace: Washington, DC, and Harvard University: Cambridge, Mass., 2000), pp. 54–55, available at URL <http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>.

[25] Albright, D. *et al.*, 'Inventories of fissile materials and nuclear weapons', *SIPRI Yearbook 1995: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 1995), pp. 320, 325.

[26] US Department of Energy (DOE), *Plutonium: The First 50 Years*: *United States Plutonium Production*, *Acquisition, and Utilization from 1944 through 1994*, DOE/DP-0137 (DOE: Washington, DC, Feb. 1996), available at URL <http://www.osti.gov/osti/opennet/document/pu50yrs/pu50y.html>.

[27] British Ministry of Defence (MOD), 'Plutonium and Aldermaston: an historical account', Apr. 2000, URL <http://www.mod.uk/publications/nuclear_weapons/aldermaston.htm>.

[28] See, e.g., Bunn (note 24) and chapter 7 in this volume.

III. Transparency: definitions and characteristics

The term 'transparency' is vague and is used in diverse ways, but almost always pointing to the principles of openness and accountability—the opposite of secrecy. Transparency can be defined as 'the quality or condition of being easily seen through, recognized, understood or detected, manifest, evident, obvious, clear'.[29] In the context of arms control, transparency is usually linked with confidence building and cooperation. Transparency measures result in greater predictability with regard to the intentions and capabilities of states, thus facilitating mutual understanding, easing tensions and reducing misperceptions.

In its simplest form, transparency is the disclosure of information that was previously kept secret, but the concept also includes the accessibility and reliability of such information. It is fundamentally a voluntary and unilateral undertaking by states for an international audience, neighbouring countries or their own citizens.[30] However, there are also cooperative and negotiated forms of transparency. During the 1990s, in the context of the bilateral nuclear security cooperation between Russia and the USA, the term was commonly employed to generically address measures that provided confidence that a declared activity was taking place.[31] In this regard, transparency is not synonymous with, but is intricately related to, the concept of verification.

Although there is no universally accepted definition of verification, there is a common understanding of its meaning as 'an activity whose purpose is to establish the degree of compliance with, or violation of, the specific terms of an agreement'.[32] Verification encompasses the technical elements of monitoring and inspection as well as information processing and evaluation. The aim of verification is to increase confidence that an agreement is being fully implemented by providing parties with the opportunity to convincingly demonstrate their compliance and to detect non-compliance, thereby deterring parties which may be tempted to cheat.[33]

Transparency is an essential precondition for accountability and effective verification.[34] There is usually a sliding scale of transparency, including: (*a*) a statement of intent; (*b*) the provision of information; and (*c*) the verification of

[29] *The Oxford English Dictionary,* vol. 11 (Clarendon Press: Oxford, 1978), p. 273.

[30] Maerli, M. B. and Johnston, R. G., 'Nuclear husbandry functions', Paper presented at the Symposium on International Safeguards: Verification and Nuclear Material Security, IAEA, Vienna, Austria, 29 Oct.– 1 Nov. 2001, p. 5, available on CD from the IAEA; and de Klerk, P., 'Transparency, confidence-building and verification and the peaceful use of nuclear energy', Paper presented at the Topical Workshop on Proliferation-Resistance in Innovative Reactors and Fuel-Cycles, Landau Network–Centro Volta, Como, Italy, 2–6 July 2001, pp. 2–3, available at URL <http://lxmi.mi.infn.it/~landnet/Doc/Reactors/klerk.pdf>.

[31] US Department of Energy (DOE), *Warhead and Fissile Material Transparency Program: Strategic Plan* (DOE: Washington, DC, May 1999), p. 10.

[32] Kokoski, R. and Koulik, S. (eds), SIPRI, *Verification of Conventional Arms Control in Europe* (Oxford University Press: Oxford, 1990), p. 5.

[33] Findlay, T., 'The verification and compliance regime for a nuclear weapon-free world', International Security Information Service, *Special Briefing Series on UK Nuclear Weapons Policy,* no. 2 (Nov. 1999), p. 1, available at URL <http://www.isisuk.demon.co.uk/0811/isis/uk/nuweapons/no2.html>.

[34] Johnson, R., 'Implications of the outcome of the NPT review conference', International Security Information Service, *Special Briefing Series on UK Nuclear Weapons Policy*, no. 5 (Jan. 2001), p. 5, available at URL <http://www.isisuk.demon.co.uk/0811/isis/uk/nuweapons/no5.html>.

information.[35] The voluntary provision of information need not always be subject to verification. Moreover, in practice, transparency in nuclear affairs is controlled and limited.[36] As experience is gained and confidence increases in step with the application of particular measures, however, parties may become inclined to share more information.

The arms control agreements implemented during the cold war have gradually introduced transparency into the relations of the two nuclear superpowers and helped reduce mutual distrust. The dissolution of the Soviet Union and the resulting changes in the international security system improved the prospects for institutionalizing and expanding the scope of transparency. High-level calls for and commitments to transparency and a variety of unilateral or bilateral actions, although limited, point in this direction. Examples include the declarations of inventories of fissile material and quantities made excess to military needs, the efforts that are under way to cooperatively dispose of part of the inventories and monitor the closure of plutonium production reactors, and the 1996 IAEA–Russian–US Trilateral Initiative.[37]

In the future, greater transparency could be brought about as part of a framework that, at least conceptually, encompasses the full accounting of nuclear assets, the agreed verification of warhead dismantlement and the irreversible disposal of surplus fissile material, as well as a prohibition on the manufacture of new warheads and fissile material. The elaboration of such a framework would require both negotiated agreements and voluntary decisions and is likely to be a very long and incremental process. If successful and supported by political goodwill, it could progressively lay the basis for nuclear disarmament verification. To this end, the accumulated experience and the technical means for verifying bilateral arms control treaties and implementing international safeguards are indispensable. Indeed, the scope, complexity and intrusiveness of verification techniques have progressively increased over time, as has confidence in their accuracy.[38]

IV. Is transparency in nuclear warheads and materials needed?

Military nuclear activities have traditionally been shrouded in secrecy. All aspects of nuclear warheads and materials—numbers, deployments and capabilities—were, and to a great extent continue to be, closely guarded national secrets.[39] During the cold war in particular, secrecy was considered to be a vital

[35] For a useful discussion of the meaning of transparency see Berkhout, F. and Walker, W., 'Transparency and fissile materials', *Disarmament Forum*, no. 2 (1999), pp. 73–84, available at URL <http://www.unidir.org/pdf/articles/pdf-art247.pdf>.

[36] See chapter 2 in this volume.

[37] See chapters 4, 5, 10 and 11 in this volume for discussion of the Trilateral Initiative.

[38] Schaper, A., 'Verifying nuclear arms control and disarmament', ed. T. Findlay, VERTIC, *Verification Yearbook 2000* (Verification Research, Training and Information Centre (VERTIC): London, Dec. 2000), pp. 57–60.

[39] In contrast, civilian nuclear programmes in the NNWS are fully transparent, largely because of the application of international safeguards administered by the IAEA.

element of security because it prevented the two superpowers from having a clear picture of each other's capabilities and strategies. In the post-cold war period, however, a wealth of information has come to light and is readily available owing to arms control, the implementation of voluntary initiatives, the contributions of the academic community and the media, and steady pressure from civil society. Rapid scientific advances and technological innovations have made a critical contribution to this end.

Although there are legitimate reasons for maintaining confidentiality in military nuclear inventories, there are a number of important reasons to increase transparency in these inventories. The overriding argument stems from the need to demonstrate that the NWS are moving forward to meet their pledges and obligations to reduce and eliminate their nuclear forces. At present no treaty obliges the NWS to declare, directly limit or accept controls on their nuclear warheads. Under the START I Treaty, Russia and the USA destroyed hundreds of strategic nuclear delivery vehicles—long-range bombers, intercontinental ballistic missiles and submarine-launched ballistic missiles—in accordance with the strict monitoring and verification provisions of the treaty. Similarly, the INF-mandated elimination of all Soviet/Russian and US intermediate- and shorter-range ground-based missiles was carried out. These reductions in delivery systems were irreversible. However, the nuclear warheads that were removed from delivery vehicles scheduled for elimination were not subject to any agreed regulation or control. Many of these warheads have already been voluntarily destroyed but, owing to the lack of transparency, there is no publicly available information on how many warheads remain in stockpiles. In addition, it is known that Russia and the USA both possess large inventories of reserve and inactive warheads, and this may also be the case in the other NWS. The potential exists for non-deployed warheads to be used to quickly reconstitute nuclear arsenals. Knowledge of the exact size of the warhead stockpiles is essential in itself and, in addition, as a precondition for proceeding with deeper reductions.

The elimination of tactical nuclear weapons also raises important issues. The delivery systems for these weapons are essentially dual-capable, that is, capable of delivering both nuclear and conventional warheads. Traditional strategic arms control measures focusing on delivery systems cannot therefore be applied to them. The only meaningful way to verify the implementation of the 1991–92 informal initiatives of presidents George H. W. Bush, Mikhail Gorbachev and Boris Yeltsin (the Presidential Nuclear Initiatives, PNIs[40]) to withdraw from active service and destroy large numbers of tactical nuclear weapons would be to apply methods of control directly to their warheads. Moreover, since the nuclear reductions undertaken by France and the UK are not constrained by legally binding agreements, it is not possible to gain assurances about their implementation.

[40] Fieldhouse, R., 'Nuclear weapon developments and unilateral reduction initiatives', *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), section II, pp. 66–73; appendix 2A (pp. 85–92) provides excerpts of the PNIs.

Transparency in military fissile materials is also limited. Knowledge of the inventories of the NWS remains incomplete. Statements about fissile material holdings and declarations about production moratoria are only politically binding. Although such statements are valuable first steps indicating the intentions of the NWS, they will have limited practical impact unless they can be effectively verified. In addition, fissile material designated excess to military needs can easily be used again to manufacture warheads unless it is permanently withdrawn from national stocks and stored under international supervision.[41] More importantly, the widespread uncertainties surrounding fissile material inventories must be reduced to a minimum in order to establish a basis for meaningful reductions.

Transparency is vitally important for a variety of other reasons. Scarcity of information about a country's nuclear capabilities may foster doubts about the willingness of the country to engage in arms control and advance disarmament. This is typically the case for the three de facto NWS—India, Israel and Pakistan—which remain outside the NPT. Conversely, the availability of information results in a well-informed civil society which, in turn, can support national strategies for both containing proliferation and reducing nuclear forces. Indeed, public debate about and scrutiny of government activities, which are essential elements of democratic societies, should also take up transparency in nuclear warheads and materials.[42]

Lifting secrecy reduces tensions and nuclear dangers. Accountability is an effective barrier against the theft and diversion of nuclear warheads and material. The ensuing cooperation at the political and technical levels builds both domestic and international confidence, thereby gradually creating the conditions in which new initiatives can be effectively negotiated and pursued.

The preamble to the NPT calls for 'the elimination from national arsenals of nuclear weapons and the means of their delivery pursuant to a Treaty on general and complete disarmament under strict and effective international control'. The commitments agreed in the Final Document of the 2000 NPT Review Conference highlighted for the first time, albeit in an abstract way, the importance of transparency and irreversibility in nuclear disarmament efforts. The conference agreed that a programme of action for nuclear disarmament will comprise, *inter alia*, 'the principle of irreversibility to apply to nuclear disarmament, nuclear and other related arms control and reduction measures' and 'increased trans-

[41] E.g., the higher estimates of Russia's excess fissile material holdings indicate that Russia could field a force 4 times the size of its current deployed strategic arsenal. 'The Wassenaar Arrangement and the future of multilateral export controls', Hearing before the Committee on Governmental Affairs, United States Senate, 106th Congress, 2nd session, 12 Apr. 2000, p. 84.

[42] E.g., in the USA an estimated total of $5.5 trillion has been spent over nearly 50 years on the production of nuclear weapons. The current cost for sustaining and operating the nuclear weapons complex is $25 billion a year. See Cirincione, J., 'The assault on arms control', *Bulletin of the Atomic Scientists*, vol. 56, no. 1 (Jan./Feb. 2000), p. 32, available at URL <http://www.thebulletin.org/issues/2000/jf00/jf00cirincione.html>. Other principal concerns include the not always well-understood environmental and public health impacts of producing, stockpiling, deploying and retiring nuclear weapons. Dhanapala, J., 'The environmental impacts of manufacturing, storing, deploying and retiring weapons', Speech at the University of Tulsa College of Law, 9 Dec. 1999, available at URL <http://disarmament.un.org/speech/9Dec99.htm>.

parency . . . with regard to the nuclear weapons capabilities and the implementation of agreements pursuant to Article VI and as a voluntary confidence-building measure to support further progress on nuclear disarmament'.[43] Other forums have also called for greater transparency in the stocks of warheads and fissile materials held by the NWS.[44]

V. Scope and objectives

The general requirements for establishing a verification regime in the context of moving towards a nuclear weapon-free world were the subject of numerous deliberations and studies during the 1990s. However, very few of them specifically addressed the technical means and procedures for introducing transparency in nuclear warheads and materials in the NWS. The main purpose of this volume is to contribute to a better understanding of the range, strengths and limitations of such technical approaches, including the necessary preconditions for their application. It surveys transparency initiatives and measures that have been implemented or proposed and analyses the factors that are impeding them. Inevitably, the main focus is on technologies developed in the framework of the Russian–US nuclear cooperation and related research and development exchanges. The two overarching considerations that are kept in focus are the depth and the irreversibility of the nuclear reductions which need to be achieved.

The emphasis of this volume is on the five NWS, principally among them Russia and the USA. Wherever relevant, observations are made on the three de facto NWS. No systematic attempt has been made to collect or review recent information on inventories of plutonium, HEU or nuclear warheads.[45]

VI. The structure of this volume

This volume consists of three parts. The chapters in Part I discuss the political implications of transparency. They examine the links between transparency and international security and the approaches followed by the NWS to increase the transparency of their nuclear assets. The evolution of transparency in Russian–US nuclear relations, arms control and security cooperation is described specifically, and the concerns of the NNWS are addressed.

The chapters in Part II focus on the technical means and procedures that have been utilized, are under development or have been proposed for introducing, building and strengthening transparency in nuclear warheads and materials.

[43] Final Document (note 4).

[44] E.g., the Tokyo Forum noted that 'irreversible reductions in nuclear forces require great transparency'. Tokyo Forum for Nuclear Non-Proliferation and Disarmament (note 7).

[45] See Albright, Berkhout and Walker (note 22) for data on the inventories of plutonium and HEU as of 1996. For warhead inventories see the estimates in, e.g., the *SIPRI Yearbook*, the NRDC 'Nuclear Notebook' section of *The Bulletin of the Atomic Scientists* and *The Military Balance* of the International Institute for Strategic Studies.

They analyse arrangements for establishing stockpile declarations, verifying warhead status and dismantlement, storing and disposing of fissile materials, and monitoring the closure or conversion of material production facilities. This part of the volume examines the challenges faced by the Russian and US nuclear warhead complexes in undertaking irreversible warhead elimination as well as a possible future role for the IAEA in institutionalizing transparency in the NWS.

Part III, the concluding chapter, summarizes the main findings of this study and presents proposals for enhancing transparency as an indispensable means for proceeding with deeper nuclear reductions.

Part I

The political dimension

2. Reflections on transparency and international security

William Walker

I. Introduction

In the years immediately following the end of the cold war, transparency was elevated to one of the primary means by which states sought to build a more robust and peaceful international order. Its various manifestations in the nuclear field are discussed in other chapters in this volume. This chapter makes broad observations about transparency and its role in international security, about the factors which have encouraged and discouraged it, and about the prospects for using transparency as an ordering device in an increasingly troubled world. In the early and mid-1990s, the present author was involved in another SIPRI study, on plutonium and highly enriched uranium, in which it seemed natural to assume that the major powers, especially the USA, would remain committed to increasing transparency in pursuit of their common goals.[1] It is distressing to observe how few of the transparency measures advocated by governments and non-governmental organizations (NGOs) at that time have been realized and how precarious the commitment to transparency is today.

After the attacks of 11 September 2001 and the discoveries that followed in their wake, the possibility that terrorists might acquire and use nuclear, biological or chemical weapons (weapons of mass destruction, WMD) is being treated very seriously, and this gives the discussion of transparency new urgency. Greater transparency will be required if states and peoples are to feel confident that these weapons are not being sought by 'rogue actors' for use against them. However, transparency carries new risks and is unlikely to be achieved unless an international environment characterized by greater cooperation and trust is established.

II. Internal and external transparency

Transparency is a necessary feature of any governmental system. The collection and management of information are essential to the exercise of authority, for organizational coordination and efficiency, social trust and the achievement of common purposes. As societies have become more advanced and complex, their reliance on and demands for transparency have increased along with the

[1] Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997).

capacities for achieving it—capacities which have been greatly enhanced in recent years by developments in information technology. On the other hand, even in the most open societies, transparency is constrained and rule-bound. Privacy and confidentiality are considered as valuable as transparency, and finding the appropriate balances between these attributes, and balances that work in specific contexts, has involved societies and their institutions in long and difficult journeys. The quest for a 'right' balance between financial confidentiality and disclosure is just one example among many.

It is useful to distinguish two realms of transparency: (*a*) the internal realm, entailing transparency within institutions (notably states and firms) and between their various parts; and (*b*) the external realm, entailing the exercise of transparency by institutions in their relations with one another. This chapter focuses mainly on external transparency. However, it should be emphasized that both types are relevant to the governance of nuclear affairs. Nuclear weapon programmes and civil nuclear industries cannot exist—and cannot be operated safely and predictably—without highly sophisticated systems for the organization and exchange of information. Even where secrecy abounds in relations between states, there should be entities within those states that know exactly what is going on and where, just as there should be lines of accountability to ensure that they are doing what they are supposed to be doing. If these internal information systems break down or cease to operate effectively, various problems will ensue. This is what confronted both the new states formed out of the Soviet Union and the international community when the Soviet Union broke apart and its organizational systems had to be reformed. The management of information is unlikely to be effective in weak or fragmenting nation states, especially when their systems of governance are simultaneously undergoing transformation.

The internal and external realms of transparency are not independent of one another. Where internal transparency is strong, as in liberal democracies, there is likely to be a greater disposition towards external transparency than in societies with autocratic forms of government. This said, democracy is not a necessary condition for external transparency: authoritarian states have repeatedly shown their preparedness to accept a measure of transparency when it has served their security interests. Nor does history suggest that democratic states will always be ready to accept such transparency.

III. Competition and secrecy, cooperation and transparency

In any competitive relationship, information about an adversary is a precious commodity. This applies to politico-military relations between states in the international system just as it applies to commercial relations between firms in the capitalist system. The ability to gather and interpret information about an adversary's plans, strategies and capabilities is an important (and in warfare a vital) source of competitive advantage. Where there is competition, there is therefore a natural tendency towards secrecy—towards keeping activities and plans as opaque to the outsider as is possible and advantageous—just as there is an urge to penetrate the secrecy of the opponent, especially when new capabilities and strategies are under development. This was taken to extremes in the field of nuclear weaponry, especially in the early years of the cold war. Information was withheld to inhibit the diffusion of technology, and a game of deception through disinformation was often played in an effort to maximize the perceptions of the risks facing the other side if it resorted to aggression.[2] In the highly charged atmosphere of this period, there was little interest in honest transparency, although there was great interest in making the opponent's activities as transparent as possible (to certain organs of the state) through espionage and other means.

The obverse is that any cooperative relationship tends to be marked by exchanges of information, sometimes involving a free and sometimes a highly managed exchange. Where there is a desire for cooperation and a desire to make it habitual, transparency usually follows. The sharing of information is both symbolic of the trust that has to underpin cooperation and a necessary means to achieve the purposes that animate it. Those purposes can involve both the avoidance of harm and the achievement of benefit.

In the late 1950s and early 1960s, the Soviet Union and the United States were driven to cooperate by the obvious dangers of unfettered nuclear competition. Especially after the shock of the 1962 Cuban missile crisis, the search began for ways to regulate Soviet–US strategic relations and reduce the risks associated with nuclear deterrence. Transparency became a central feature of the arms control measures that were negotiated, but its scope was tightly limited and methods were chosen to minimize its intrusiveness. Certain kinds of information were collected and exchanged, notably on the number and types of delivery vehicles, but the research and development (R&D) and production systems, together with the systems of command and control, remained essentially out of bounds, as did information on warhead designs. The challenge was to devise a regulatory approach which created room for cooperation in a relationship that remained highly competitive and mistrustful and one that created zones of 'controlled transparency' in an environment in which secrecy remained the dominant condition. From the early 1960s, the need for arms control was not contested by either the Soviet or the US government (at least prior to the presidency of Ronald Reagan), but the means of achieving it was difficult to negotiate, partly because concessions constantly had to be made to sceptics in both states. The USSR remained especially suspicious of measures that would open its facilities and activities to greater foreign scrutiny, fearing that it would expose itself to espionage.

[2] Nuclear deterrence nevertheless relied on certain capabilities and intentions being made transparent. An example was the USSR's conducting of nuclear tests in the late 1940s and 1950s. Besides contributing to the knowledge of weapon performance and design, they were intended to demonstrate to the USA and its allies that the USSR now shared their ability to inflict unacceptable damage through nuclear reprisal. The classic work on deterrence theory and the role of communication in deterrent relations is Schelling, T., *The Strategy of Conflict* (Harvard University Press: Cambridge, Mass., 1960 and 1980).

IV. Transparency as an instrument of non-proliferation

In the 1950s and 1960s, methods were being sought to provide confidence in the renunciation of nuclear weapons by states with extensive technological capabilities, such as Germany and Japan. Transparency was again central to the task. Here it should be noted that transparency has two connotations: (*a*) the condition of being transparent (outsiders can see in); and (*b*) the desire to be transparent (the agent opens itself voluntarily to the outsider). In the mid-1960s, a concern of several states was to assure neighbouring states and the great powers that they could trust that they would not use the materials and expertise acquired for civil nuclear industries to develop weapon capabilities. A system of verification had to be devised that was fully effective, that invited trust, that did not unduly infringe on state sovereignty and that respected the need for confidentiality of industries operating in competitive international markets. The outcome was the international safeguards system, which: (*a*) adopted the methods of material accountancy and exploited distinctive attributes of fissile materials to provide confidence that any diversion could be detected; (*b*) vested authority for gathering information and conducting inspections in an international organization, the International Atomic Energy Agency (IAEA); (*c*) envisaged a relationship between the IAEA and the safeguarded state that was more cooperative than adversarial; and (*d*) honoured demands for confidentiality. The unprecedented invasion of sovereignty which all of this entailed could not be achieved without granting the safeguarded state influence over monitoring procedures and without giving it some protection against abuse. Although the requirements for transparency were more sweeping than in the field of strategic nuclear arms control, transfers of information were highly controlled and rule-bound, as any reading of the IAEA Model Safeguards Agreement will attest.[3]

Transparency also became an important facet of export controls when the Nuclear Suppliers Group (NSG) Guidelines were negotiated in the mid-1970s.[4] The NSG Guidelines required the NSG participating countries to consult with one another on proposed exports and to obtain information from importers on the precise uses to which the goods would be put. The requirement for governments to gather and share information encouraged caution. It also required governments to exert greater control over their own exporting industries while providing them with the internal authority to establish the necessary bureaucratic rules and procedures.

[3] IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), INFCIRC/153 (Corrected), June 1972, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>.

[4] The NSG Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Materials, Software, and Related Technology, as they are now called, are incorporated in IAEA document INFCIRC/254. They have been revised several times since 1978. INFCIRC/254 and the revisions are available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/infcirc254.shtml>.

Three 'systems of external transparency' therefore developed in the service of arms control and confidence building during the cold war. The first was developed bilaterally by the USA and the USSR as a means of demonstrating confidence in agreements which limited their deployments of nuclear arms. The second was instituted multilaterally but exercised bilaterally between the IAEA and non-nuclear weapon states (NNWS) as a means of verifying renunciations of nuclear weapons. The third was also multilateral, involving the exchange of information between supplier states which had set themselves the task of exercising more effective control over the international diffusion of nuclear materials.

However, these were not the only systems of transparency. A much larger, if 'underground', transparency system was also established—that involving intelligence gathering and espionage, or 'national technical means' (NTM), as it came to be euphemistically described. The approach was very different from that adopted in international treaties and agreements. Here the objective was to render the activities and intentions of an opponent transparent, while keeping that transparency—and the means of attaining it—hidden from the state that was being observed. As known from experiences in the cold war, this non-voluntary transparency was a source of persistent friction between the two sides, but it provided them with a modicum of confidence in their ability to manage the conflict without descent into war. It was buttressed by developments in remote sensing from the 1950s onwards. As Steven E. Miller has observed, 'technological developments made it possible to peer deeply and comprehensively into the territory of other states without their cooperation'.[5]

Thus there are two kinds of external transparency, *voluntary* and *non-voluntary*. The one is exercised through treaty processes and the other through NTM, which are normally not regulated internationally. While functionally and institutionally separate, there is a necessary but awkward symbiosis between them that has become fundamental to the achievement of security goals.

V. The post-cold war intensification of transparency measures

A great extension, even intensification, of external transparency measures of the voluntary kind was promoted in the decade from about 1985 to 1995. It drew its energy from four major developments: (*a*) the end of the cold war; (*b*) the break-up of a major nuclear weapon state (NWS), the USSR; (*c*) the exposure of Iraq's nuclear weapon programme after the 1991 Persian Gulf War; and (*d*) the emergence of nuclear disarmament as a significant policy issue. Each of them is considered in the sections below.

[5] Miller, S. E., 'Arms control in a world of cheating: transparency and non-compliance in the post-cold war era', eds I. Anthony and A. D. Rotfeld, SIPRI, *A Future Arms Control Agenda: Proceedings of Nobel Symposium 118, 1999* (Oxford University Press: Oxford, 2001), p. 178.

The end of the cold war

Among the many reasons why greater importance was attached to transparency after the end of the cold war, three stand out. First, transparency became symbolic of the cooperative relationship that the East and the West were striving to establish after decades of antagonism. The willingness of the new states formed out of the USSR to embrace transparency measures for security gains was also seen as a test of their commitment to democratic norms and the market economy. China's pronounced, if still tentative, embrace of transparency measures, especially in the form of on-site inspections associated with multilateral treaties, was equally important. Although the forces of democratization were kept at bay by the Chinese Government, economic modernization required reasonably settled political relations with the USA and other states. Cooperation in the United Nations Security Council and in multilateral forums also became an important means of mending fences after the 1989 Tiananmen Square massacre. In addition, multilateral arms control came to serve the Chinese interest of avoiding the emergence of nuclear-armed regional competitor states and limiting the economic cost of sustaining and modernizing its nuclear deterrent.

Second, arms control measures that had been on the cards for many years but could not be negotiated suddenly became possible when China, Russia and other states indicated their preparedness to open up to multilateral inspection. Prominent among these agreements in the 1990s were the 1990 Treaty on Conventional Armed Forces in Europe, the 1993 Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention, CWC) and the 1996 Comprehensive Nuclear Test-Ban Treaty (CTBT). Whereas multilateral verification had been instituted only in the nuclear field and in the NNWS (the application of European Atomic Energy Community, Euratom, safeguards in France and the UK being the one exception), its extension to the NWS and other security fields now seemed possible.[6] This extension of transparency was actively promoted by the USA as one of the main instruments for achieving security in the complex multipolar international system that appeared to be emerging. Among other things, it would help mitigate the security dilemmas that tend to be rife when states are jockeying for advantage in a multipolar system.

Third, the purposes of strategic nuclear arms control were changing. Arms reductions were being sought instead of arms limitation, and an emphasis was being placed on rendering the reductions irreversible. This entailed *inter alia* the verified destruction of armaments and the removal of fissile materials from military cycles prior to their eventual disposition. All of these tasks required

[6] Some IAEA safeguarding of facilities in the NWS was permitted under Voluntary Offer Agreements with the IAEA, but it was very limited. For further discussion of these agreements, see chapter 11 in this volume.

states to commit themselves to greater openness and to the consideration of novel verification measures.[7]

The break-up of the USSR

After the break-up of the USSR in 1991, its nuclear weapon assets were located in four former Soviet republics—Belarus, Kazakhstan, Russia and Ukraine—raising many questions about ownership, about the methods and distribution of governmental control, and about the conditions under which the assets would be returned to Russia. Policy making both inside and outside the former Soviet Union (FSU) depended on an extensive auditing of weapons and fissile materials and identification of the weapon-manufacturing facilities. By the mid-1990s, the FSU's huge and previously hidden nuclear infrastructure had been mapped and a reasonable, if not sufficiently precise, knowledge of its historic functions had been assembled. NGOs played an important part in this process, seizing a moment when most governmental institutions in the FSU were prepared to open their doors to outsiders.[8]

At the same time, the USA made increased transparency a central objective in its relations with Russia. It did so partly to further the verification and irreversibility of arms reduction agreements and partly to encourage openness and sound management across the Russian nuclear infrastructure. An example was set by the US Department of Energy's 1993 Openness Initiative which, although instigated mainly for domestic reasons, assembled and published detailed information on US fissile material inventories and nuclear explosions.[9] The attempt to persuade the Russian Government to move in a similar direction resulted in the 1994 Gore–Chernomyrdin Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons.[10] Unfortunately, progress became increasingly difficult as Russian–US relations soured in the mid-1990s and as the Russian Government failed to reform its Ministry

[7] They included the verification of warhead dismantlement. See, e.g., British Atomic Weapons Establishment (AWE), *Confidence, Security and Verification: The Challenge of Global Nuclear Weapons Arms Control*, AWE/TR/2000/001 (Aldermaston: Reading, Apr. 2000), available at URL <http://www.awe.co.uk/main_site/scientific_and_technical/publications/pdf_reports/awe_study_report.pdf>; and Fetter, S., *Verifying Nuclear Disarmament*, Occasional Paper no. 29 (Henry L. Stimson Center: Washington, DC, Oct. 1996).

[8] See, especially, Cochran, T. and Norris, R., *Russian/Soviet Nuclear Warhead Production*, *Nuclear Weapons Databook*, Working Paper, NWD 93-1 (Natural Resources Defense Council: Washington, DC, Sep. 1993); Albright, D., Berkhout, F. and Walker, W., SIPRI, *World Inventory of Plutonium and Highly Enriched Uranium 1992* (Oxford University Press: Oxford, 1993); and Carnegie Endowment for International Peace and Monterey Institute of International Studies, *Nuclear Successor States of the Soviet Union* (Carnegie Endowment for International Peace: Washington, DC, and Monterey Institute of International Studies: Monterey, Calif., 1994).

[9] The Openness Initiative was launched by Hazel O'Leary, Secretary of Energy in the first administration of President Bill Clinton, partly in response to public demands for information about the inventories and conditions at US nuclear weapon production sites, such as Rocky Flats, which were scheduled for closure. See Ferm, R., 'Nuclear explosions, 1945–93', *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), p. 309; and chapter 3, section IV, in this volume.

[10] The Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons is available at URL <http://www.ceip.org/files/projects/npp/resources/summits4.htm>.

of Atomic Energy (Minatom), which retained control over the organizations involved in nuclear weapon R&D and production.

Iraq's nuclear weapon programme

The 1991 Persian Gulf War led to the exposure of a massive nuclear weapon programme in Iraq, which it had mounted in spite of the fact that it was a non-nuclear weapon state party to the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT) and had submitted to full-scope IAEA safeguards. It became obvious that the transparency practised through the safeguards agreements embodied in INFCIRC/153 was insufficient to ensure detection of clandestine weapon activities and that intelligence agencies in the USA and elsewhere had failed to appreciate the scale and advanced stage of Iraq's programme. The result was the launch of the IAEA's '93 + 2' programme,[11] which sought to bring about a comprehensive reform of the IAEA safeguards system, culminating in agreement in 1997 on the Additional Safeguards Protocol to INFCIRC/153.[12] Contemporaneously, many governments launched reviews of their approaches to gathering and sharing intelligence information on WMD programmes. These developments led (in principle if not yet sufficiently in practice) to a widening of access to sites where the IAEA could conduct inspections and to an increase in the information that states with safeguards agreements with the IAEA were routinely expected to supply to the Agency. The Iraqi experience also increased the resources that intelligence agencies devoted to the monitoring of potential weapon programmes and led to the establishment of channels of communication between these agencies and the IAEA.

Nuclear disarmament

In the early to mid-1990s serious attention began to be paid to the means by which nuclear disarmament might be achieved and sustained. This arose from the experience of implementing disarmament in South Africa and Iraq,[13] from the development of measures such as those under the CTBT and the proposed Fissile Material Cut-off Treaty (FMCT), which were useful to global disarmament, from the need felt by the NWS to extol disarmament in order to secure

[11] Programme 93 + 2, to strengthen the effectiveness and improve the efficiency of safeguards, was launched in 1993 and was to make recommendations within 2 years. The programme took 4 years to complete, with final approval granted by the IAEA Board of Governors in May 1997.

[12] IAEA, Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540, Sep. 1997, and subsequent corrections, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Numbers/nr501-550.shtml>.

[13] For a discussion of the means by which South Africa was disarmed and of the background to its decision see Albright, D., *How South Africa Abandoned Nuclear Weapons* (Henry L. Stimson Center: Washington, DC, 1997).

the NPT's indefinite extension in 1995 and from the activism of many NGOs.[14] Studies conducted at this time pointed towards the need for an unprecedented increase in transparency and in the resources devoted to verification.[15] Complete disarmament would require all states to reveal their material holdings in great detail and to satisfy safeguards agencies through exercises in 'nuclear archaeology' that no materials were missing from their declared inventories. Furthermore, the open access and unhindered challenge inspections sought in the Additional Safeguards Protocol would have to be universalized. Disarmament would not be achievable without a genuine commitment to transparency by states that had possessed nuclear weapons or the capabilities to manufacture them. Moreover, as important as transparency itself, there would have to be confidence that states would respond promptly and forthrightly to any attempted 'breakouts'. It was recognized that the transparency built into disarmament agreements would be a weak instrument if there were no reliable means of responding to deception. All of these conclusions were underlined by the experiences in Iraq—the extensive efforts needed to expose and destroy its weapon capabilities, as well as the vulnerability of states and international regimes to acts of non-compliance and breakout and the problems that arise when great powers disagree on how and whether to enforce compliance.

VI. The deterioration of arms control

If the arms control measures proposed in the early and mid-1990s had come to fruition, and if states had supported and ratified treaties that had been successfully negotiated, there would be greater interstate transparency today. In the event, few of the objectives have been realized. The list of disappointments is long and is becoming longer. It includes the START II Treaty[16] and the CTBT (not in force); the FMCT and START III (not negotiated); the BTWC[17] and the Trilateral Initiative (not concluded);[18] the Additional Safeguards Protocol (too few adherents); and the UN Special Commission on Iraq (UNSCOM), the UN Monitoring, Verification and Inspection Commission (UNMOVIC) and other approaches for achieving the verified disarmament of Iraq (paralysed until given a fresh boost by the UN Security Council in 2002).

[14] Under Article IX.3 of the NPT, the states parties were required to decide, 25 years after entry into force (it entered into force in 1970), whether and for which period or periods to extend the treaty's lifetime.

[15] See, e.g., Fetter (note 7).

[16] The 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms, which never entered into force. On 14 June 2002, as a response to the expiration of the ABM Treaty on 13 June, Russia declared that it will no longer be bound by the START II Treaty.

[17] The 1972 Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (Biological and Toxin Weapons Convention).

[18] If it is concluded, the Trilateral Initiative will entail an agreement between the IAEA and the Russian and US governments on the international verification of fissile materials and parts removed from dismantled nuclear warheads. See also chapters 4, 5, 10 and 11 in this volume.

The reasons for this record of failure are not easily summarized. It began with the political changes in Russia and the USA following the Duma and congressional elections of 1993 and 1994, respectively, which allowed an increasingly insular and mistrustful cast of politicians and their advisers to exert influence over foreign and security policy. Most treaties became unratifiable in Russia and the USA. The retreat from a cooperative and universalist approach to nuclear politics, with its inherent preference for transparency, was exacerbated by India's refusal to sign the CTBT in 1996 and by India's and Pakistan's nuclear explosions in 1998. The nadir was reached with the George W. Bush Administration's disparagement of multilateral arms control, the US withdrawal from the 1972 Treaty on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty),[19] and the exclusion of any verification and transparency measures from the May 2002 Russian–US Strategic Offensive Reductions Treaty.[20]

Although several states played a part in shifting nuclear policy off its previous track, the USA's actions have been the most influential and therefore deserve particular attention. Given its contemporary political, military and economic power, the USA has great influence—through its policies and the example that it sets—over the behaviour of other states. Its influence over their stances on transparency is especially strong. It should be recalled that it has been the USA, more than any other actor, that has historically advocated transparency as a means of building trust between states and avoiding security dilemmas. In gaining their adherence to transparency, the USA has often had to induce states that lack its traditions of openness and democratic accountability to accept measures that were foreign to their experience. If the USA hedges its support for transparency and for the arms control measures in which it is embodied, other states, including China and Russia, might quickly revert to their former preference for secrecy.

Why did the USA move so strongly against the measures, and the ordering strategy, that it had propounded over so long a period? There are four main reasons. The first reason was the growing mistrust of states that were not allied to the USA, a mistrust that had become visceral in some influential communities by the end of the 1990s. Encouraged by China, Iran and Iraq's actual or alleged misdemeanours and by the increasingly Manichaean world view of the US public and media, it came to be assumed that 'states will cheat' irrespective of commitments made under international law. This enveloping mistrust, rampant in the Republican Party, which gained the majority of seats in Congress in 1994, appeared justified *inter alia* by the behaviour of Iraq and North Korea (and by accusation Iran), which had sought cover for their nuclear weapon activities by joining the NPT; by the USSR's and then Russia's massive viola-

[19] For a discussion of the US withdrawal from the ABM Treaty and the responses to it see Kile, S. N., 'Ballistic missile defence and nuclear arms control', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 70–77.

[20] The full text of the Strategic Offensive Reductions Treaty (SORT) is available at URL <http://www.fas.org/nuke/control/sort/sort.htm>. The treaty will enter into force when it has been ratified by both signatories. For the implications of SORT see 'Special Section', *Arms Control Today*, vol. 32, no. 5 (June 2002), pp. 3–23.

tion of the BTWC; and by allegations that China had engaged in espionage in US nuclear weapon laboratories.[21] To make matters worse, the USA began to lose confidence that it could count on international support when acts of duplicity were revealed. Especially after the USA and its European allies disagreed with China and Russia over the military interventions in the Balkans and in Iraq, the UN Security Council lost its ability to act decisively, if at all, in response to acts of non-compliance. As Brad Roberts pointed out, there seemed to be no reliable political answer to the question posed in 1961 by Fred Iklé: 'After detection—what?'.[22] Only when the US Government forced Iraq's non-compliance back on the agenda in 2002 was the UN Security Council persuaded to act.

Second, the financial cost of multilateral verification was rising just as the US belief in its effectiveness was diminishing. The strengthened IAEA safeguards system, together with the verification systems proposed for the BTWC, the CTBT, the CWC, the FMCT and the START treaties, would have required annual expenditures running into several hundred million dollars, a large share of which would have had to be paid by US taxpayers and partly drawn from the US defence budget. The US Congress was becoming increasingly resistant to this level of outlay on measures whose worth it had come to doubt.

Third, the perceived security risk had shifted from an emphasis on nuclear explosives and materials to an emphasis on ballistic missiles which could be armed with nuclear, chemical or biological warheads. The spread of missile capabilities in the 1980s and the 1990s came to be regarded as the main problem needing attention. Especially if the states possessing missiles could not be deterred by the threat of military reprisals, ballistic missiles could expose the USA to blackmail and might reduce its willingness to deploy armed forces in the Middle East and elsewhere. The imminence of the missile threat was stressed by the influential 1998 Rumsfeld Commission Report, whose gloomy conclusions seemed justified by North Korea's firing of a ballistic missile over Japan a month later.[23] Since the Missile Technology Control Regime (MTCR) had been established late in the day (1987) and lacked universal participation, legal underpinnings and instruments of verification, it could provide only a limited solution.[24] Influential groups in the USA became preoccupied (some

[21] On cheating and arms control see Miller (note 5).

[22] Roberts, B., 'Revisiting Fred Iklé's 1961 question, "After detection—what?"', *Nonproliferation Review,* vol. 8, no. 1 (spring 2001), pp. 10–24. On problems of achieving compliance see also Müller, H., 'Compliance politics: a critical analysis of multilateral arms control treaty enforcement', *Nonproliferation Review*, vol. 7, no. 2 (summer 2000), pp. 77–90, both available at URL <http://cns.miis.edu/pubs/npr/>.

[23] Executive Summary of the Report of the Commission to Assess the Ballistic Missile Threat to the United States, US Congress, 15 July 1998, URL <http://www.house.gov/hasc/testimony/105thcongress/BMThreat.htm>.

[24] On the limitations of the MTCR and on possible solutions to the problems posed by the availability of missile technology see Smith, M., 'Missile proliferation, missile defenses and arms control', ed. S. Parrish, *International Perspectives on Missile Proliferation and Defenses*, Occasional Paper no. 5 (Center for Nonproliferation Studies, Monterey Institute of International Studies: Monterey, Calif., and Mountbatten Centre for International Studies, University of Southampton: Southampton, 2001), pp. 24–32, available at URL <http://cns.miis.edu/pubs/opapers/op5/op5.pdf>.

would say obsessed) with finding a technological response in the form of missile defences.

Fourth, scientific and industrial communities in the USA began to see opportunities to develop new and improved technological capabilities unencumbered by international restrictions. Where the Revolution in Military Affairs had given the USA an unchallenged lead in conventional warfare, developments in missile defence and space technology might provide it with a strategic advantage that could not be matched by other states for years or even decades to come. Their advice was heeded by the Bush Administration, which was courting industrial support, regarded technological supremacy as the surest foundation for national security and found it instinctively distasteful that the USA was limiting its freedom to innovate, whatever the benefits following from mutual restraint. The CTBT, the CWC and the BTWC, unlike the NPT, constrained technological development and opened the USA to compulsory international verification. For many in the United States, the ABM Treaty came to symbolize the loss of freedom to exploit what they perceived to be the USA's greatest asset—the capacity to innovate.

Terrorism and transparency

In the second half of the 1990s, there was a move away from both bilateral and multilateral arms control. Many of the treaties and agreements concluded in previous times remained in force, but most proposals on the long negotiating agenda established in the early to mid-1990s came to nothing. Transparency and cooperative security were still preached when governments came together, for example, at the 2000 NPT Review Conference and in its agreed Final Document,[25] but the trend was in the other direction. In developing their responses to the threat of international terrorism demonstrated by the attacks of 11 September 2001, governments have therefore been denied (and have denied themselves) the opportunity to draw on a healthy stock of multilateral treaty instruments and processes.

The state has customarily been regarded as the main 'object of concern' when developing instruments to exert control over WMD and their associated capabilities. A perceptual adjustment had to be made in the 1990s with the emergence of the phenomenon of the 'rogue state', a state that was prepared to violate international norms and obligations in pursuit of its aims. Now international society has to address the risks posed by non-state actors, which by their very nature place themselves beyond governmental regulation and the rule of law.[26]

[25] Final Document of the 2000 Review Conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2000/28, 24 May 2000, available at URL <http://www.iaea.org/worldatom/Press/Events/Npt/npt-2000.shtml>.

[26] Warnings of the dangers of nuclear terrorism date back to the 1970s. See, e.g., Willrich, M. and Taylor, T., *Nuclear Theft: Risks and Safeguards* (Ballinger: Cambridge, Mass., 1974). However, the risk that a terrorist act could involve nuclear material has been treated as secondary until recently.

For terrorist groups, secrecy is fundamental to survival and the pursuit of their ends, whether in national or international contexts. Penetrating that secrecy will always be the first line of defence against such actors. The high priority now being given to containing the threat of international terrorism potentially moves non-proliferation policy deeper into the unregulated world of intelligence gathering and away from the treaty-bound world of external transparency and verification. It also implies that greater attention will have to be given to internal transparency and control in so far as states have to rely on their own institutional devices to protect their citizens against the 'enemy within from without' and to satisfy other states that the internal protection thereby provided will prevent the emergence of a general hazard.

While the balances between them are bound to be adjusted, neither intelligence gathering nor international verification, and neither internal nor external transparency, can in practice provide the protection—and confidence in that protection—that is now required. Only through some combination of all of these approaches can effective security be established. Furthermore, that combination has to be found and practised by the agencies of states acting cooperatively inside and across national frontiers.

There are two essential functions of any non-proliferation policy that addresses terrorist threats: (*a*) the *detection* of WMD capabilities and efforts by actors to develop (and disguise) such capabilities; and (*b*) the *denial of access* to the expertise and material required to manufacture and deliver the weapons. With regard to detection, the first responsibility resides with individual states to discover and to police clandestine activities within their own territories. It therefore involves *inter alia* an exercise of internal transparency practised in conjunction with other states where activities are transnational. This effort is buttressed, in some but not all states, by the instruments of voluntary external transparency (normally international safeguards) which, if effectively applied, enable the state to win confidence that no such activities are taking place on its territory. If, as is often the case, states lack the means, authority or intent to exercise internal transparency, and if external transparency of the voluntary kind is ineffective or non-existent, then the only resort is to intelligence gathering by outside powers. However, this is no panacea. While intelligence agencies may have considerable means at their disposal, their activities inevitably entail the penetration of a sovereign state and, unless the target state consents to the operations, will be resented and resisted. As experiences with Iraq and al-Qaeda have shown, intelligence operations are also extremely fallible.[27] Even the most well-equipped intelligence agency can easily become blinded to the true nature and extent of clandestine activity if it cannot penetrate institutions.

As far as the denial of access to weapon materials and capabilities is concerned, intelligence agencies have a comparatively small role to play beyond monitoring trade and the people who might be engaged in covert transactions.

[27] On the recent failings of the US Central Intelligence Agency see Powers, T., 'The trouble with the CIA', *New York Review of Books*, vol. 49, no. 1 (17 Jan. 2002), available at URL <http://www.nybooks.com/articles/15109>.

The main objectives must be to develop comprehensive inventories of materials and capabilities, to ensure that they are *all* held in installations that are *completely* secure and to establish programmes for rendering them unusable in the medium and long terms. These objectives can be achieved only through states acting singly or in collaboration through formal processes such as the US Cooperative Threat Reduction programme, which has sought to place nuclear matériel in the states of the FSU beyond the reach of hostile actors.[28] There is little if any difference here between the measures aimed at inhibiting access by states or non-state actors. Their effectiveness depends, first, on the abilities of states to exercise internal transparency and control and, second, on their abilities jointly to mount programmes that will achieve the desired ends. Because the principal stocks of weapon material are in the eight states that possess nuclear weapons—China, France, Russia, the UK and the USSR and the de facto NWS India, Israel and Pakistan—international security depends heavily on the cohesion and resources of those eight states, on their interrelations and on the seriousness with which they take their responsibilities.

It therefore seems self-evident that the containment of catastrophic terrorism relies, just as does the containment of weapon proliferation in its traditional form, on the development of a rich panoply of measures. Moreover, the measures adopted in the fields of arms reduction and non-proliferation (whether aimed at state or non-state actors) are interconnected, especially in so far as the main capabilities and stocks of nuclear materials are to be found in the NWS. The implication is that failure in one domain will have repercussions in other domains: relations between the NWS cannot be allowed to 'freewheel' if an effective campaign against the acquisition of WMD by state and non-state actors is to be mounted. Nor can states and peoples be expected to gain confidence that WMD will not be used in anger by 'rogue actors' if transparency is lacking in all its forms.

Come what may, transparency will play an important role as states try to restructure security policies to deal with threats from *all* actors. To be effective and acceptable, however, the processes and practices of transparency will have to be subjected to a set of profound questions, particularly about the relationship between intelligence gathering and verification. How can the secretive, informal and largely unaccountable practice of intelligence gathering be reconciled with the more open, formal and rule-bound practice of treaty-based transparency? If the 'war against terrorism' requires an unprecedented level of cooperation between intelligence services, how can that cooperation be institutionalized and civil rights and the rights of less powerful states be protected? How can international organizations entrusted with treaty verification maintain their integrity if intelligence gathering and transparency measures become inter-

[28] For discussion of the Cooperative Threat Reduction programme and the steps needed to strengthen and extend it see Bunn, M., Holdren, J. P. and Wier, A., *Securing Nuclear Weapons and Materials: Seven Steps for Immediate Action* (Project on Managing the Atom, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, and Nuclear Threat Initiative: Cambridge, Mass., and Washington, DC, respectively, May 2002), available at URL <http://bcsia.ksg.harvard.edu/BCSIA_content/documents/SevenSteps.pdf>; and chapters 4 and 5 in this volume.

mingled in the eyes of states? How, on the other hand, can those organizations inspire confidence if they are enied access to national intelligence? Governments will have to tread extremely carefully when deciding how to extend the reach of their intelligence services and how to manage the interface between intelligence agencies and the institutions involved in treaty verification. They should be especially concerned about the risks that the integrity of verification agencies, and of the IAEA above all others, could be compromised by the ill-judged management of relationships with intelligence agencies.

Transparency and weapon design

One issue in particular has troubled states since the beginning of the nuclear age and has become even more troubling since 11 September 2001. It concerns the public availability of information pertaining to the design and use of nuclear weapons. Although much information on the science and technology of nuclear explosives has entered the public domain since the discovery of nuclear fission in 1938, it has usually been assumed to have value only to states which possess the resources to mount significant weapon programmes and wish to arm themselves for deterrence purposes. This assumption can no longer be regarded as valid given the additional diffusion of knowledge through the Internet, the possible theft of weapon-grade material from sites in the FSU or elsewhere, the mobility of weapon designers and the realization that terrorists are prepared to cause mass casualties. Terrorist groups may also be satisfied with a crude device (including a radiological device) that can serve as a 'weapon of mass effect'.

There is no obvious solution to this problem. No doubt intelligence agencies will be monitoring pertinent Internet sites and their users. The only comfort comes from the experience with actual weapon manufacture: it takes much more than knowledge of the workings of nuclear warheads to manufacture a usable weapon. Controls must therefore focus on the diffusion of designers more than on designs, and on weapon-grade materials and the equipment used in weapon manufacture.

VII. Conclusions

Transparency is complex in both concept and practice. It is multidimensional, it is not always a good thing, and transparency measures have to be orderly, honest and widely adopted if they are to win the confidence and support of states. There has to be trust in the processes of transparency, in the intentions of those pressing for transparency, and in the capacity and willingness of states to respond to its abuse. Although that trust has been eroded in recent years, transparency has been, and will remain, an indispensable device for limiting the dangers posed by nuclear weapons.

The world today faces a paradox. The need for stronger transparency measures and for their wider application, and the availability of technical means for meeting that need, have never been greater, as other chapters in this volume attest. Yet the political scope for institutionalizing transparency, and for further developing the instruments of verification, has seldom been so constrained, for all the reasons discussed above. Unfortunately, the international cooperation that followed the 11 September 2001 terrorist attacks has not yet yielded results in the field of arms control and transparency. Nor have the nuclear arms reductions announced in November 2001 by presidents George W. Bush and Vladimir Putin provided reassurance, since they are not yet legally binding and are not subject to verification.[29]

Although this situation has been caused by many factors, the current malaise cannot be remedied if the US Government remains antagonistic to arms control. US concerns about the efficacy of security regimes in the post-cold war environment have not been groundless. Where its recent approach invites criticism is in its lack of balance. To believe that a hegemonic state, however great its resources, can achieve security in the contemporary international system just by enhancing its military capabilities and threatening retribution is to play with illusion, just as it is an illusion to believe that all the answers lie in cooperative security. As the present author has observed elsewhere, nuclear 'order is much more than a structure of power and a set of deterrent relations, just as it is much more than a security regime rooted in international law. It is a complex edifice founded on instruments of *both* power and law which is held together by mutual interest *and obligation*'.[30]

Similarly, it is an illusion to believe that the USA can freely and without consequence choose the arms control treaties and institutions it will support—that it could withdraw from the CTBT, the BTWC and the ABM Treaty while expecting other states to continue honouring commitments to the NPT and other treaties that the USA still values. Ambassador Richard Haass, Director of the Policy Planning Staff of the US Department of State and a rare exponent of multilateralism within the Bush Administration, has stated the US position.

> Today, at the dawn of a new century, the Bush Administration is forging a hard-headed multilateralism suited to the demands of this global era, one that will both promote our values and interests now and help structure an international environment to sustain them well into the future. . . . Our desire to work cooperatively with others does not mean, however, a willingness to agree to unsound efforts just because they are popular. . . . We have, moreover, demonstrated that we can and will act alone when necessary.

[29] In these respects, the 2002 SORT (see note 20) falls far short of the previously proposed START III accord. START III did not envisage any reserve stocks of nuclear warheads that could be returned to use and was expected to include substantial measures to verify warhead dismantlement.

[30] Walker, W., 'Nuclear order and disorder', *International Affairs*, vol. 76, no. 4 (Oct. 2000), pp. 703–24.

Our right to self-defense is unquestioned. . . . A commitment to multilateralism need not constrain our options—done right, it expands them.[31]

Unfortunately, the Bush Administration has so far shown rather little penchant for even this 'hard-headed' multilateralism.

If the great powers come to regard arms control as an instrument to be used strictly at their own discretion and convenience, the institution of arms control will inevitably lose prestige and the capacity to shape the behaviour of states. The same applies to transparency. States cannot be expected to open their activities to the scrutiny of other states if the latter are barring their doors. A respect for reciprocal obligation remains essential to transparency and to the establishment of a durable security order.

The external transparency discussed in this chapter is fundamentally a servant of international law and of the attempt by states to adopt common norms and rules of behaviour in their mutual interest. It has little meaning or utility outside that framework. Transparency of the voluntary kind thus depends on the strength of commitment to international law and its application in arms control. Transparency cannot play its part if that commitment no longer lies at the centre of the security strategy of states. One can only hope that the crisis over Iraq that is emerging as this book goes to press will end with a stronger commitment to cooperative measures.

[31] Haass, R., 'Multilateralism for a global era', Speech at the Carnegie Endowment for International Peace Conference After September 11: American Foreign Policy and the Multilateral Agenda, 14 Nov. 2001, Washington, DC, available at URL <http://usinfo.state.gov/topical/pol/terror/01111413.htm>.

3. Nuclear weapon states and the transparency dilemma

*Camille Grand**

I. Introduction

Over the past 10 years, 'transparency' has become a buzzword in national and international politics, at least in the democracies. As the media, citizens, non-governmental organizations (NGOs) and shareholders pressure corporations, international institutions and governments to implement greater openness, transparency is becoming the norm rather than the exception. Legal obligations and societal pressure have led to increasingly open societies. The secrecy that characterized government policy and corporate decision making is constantly being reduced in democratic societies. Chief executive officers and ministers must not only account for their actions as leaders but also provide detailed information on the salaries and benefits they receive. International organizations such the United Nations, the International Monetary Fund, the World Bank and the European Union (EU) can no longer design policies without being transparent about their purposes and funding. Transparency has also become closely associated with another important concept—accountability. In order to meet the standards of transparency and accountability, businesses and international organizations publish detailed reports on their activities. Transparency and accountability are thus increasingly perceived as indispensable tools for establishing legitimacy.

A number of examples can be cited that point to the growing importance which international bodies attach to transparency as a guiding norm for decision making. The UN has developed, in particular since the launch of Secretary-General Kofi Annan's reform programme, a specific strategy for communication and public information. As the Secretary-General stated in his report to the Millennium Assembly, 'A more people-oriented United Nations must be a more results-based organization, both in its staffing and its allocation of resources. . . . When fully implemented this will encourage greater efficiency and flexibility, while at the same time enhancing transparency and the Secretariat's accountability to Member States'.[1] The work and decision-making process of the UN Security Council are also becoming more transparent to meet

[1] Annan, K. A., *We, the Peoples: The Role of the United Nations in the 21st Century* (United Nations: New York, 2000), p. 73, available at URL <http://www.un.org/millennium/sg/report/full.htm>.

* This chapter was written in a personal capacity and does not represent the views of any government or institution.

these new standards. In addition, the EU has committed itself to transparency. As Romano Prodi, President of the European Commission, expressed it, 'I appeal to Europe's citizens to break the apathy barrier and take a close interest in our progress. Watch us. Find out what we are doing. Consult the register of my correspondence. Then tell us what *you* think. We are committed to the highest standards of transparency and accountability'.[2] Finally, NATO increasingly emphasizes the importance of transparency in its deliberations and decision making. For example, the 1999 Strategic Concept cites 'transparency' as a guiding principle in various policies no fewer than seven times.[3]

Given the nature of nuclear issues and the public concern to which they give rise, it would be strange to expect them to be exempted from these transparency standards. In the civilian nuclear sector, most private and public companies now realize that their survival depends on a form of corporate governance involving a high degree of transparency. Obviously, translating this principle into corporate practice requires time and effort, but as legal obligations and pressures from civil society grow the demands for transparency will have to be met.

Governments are under similar pressure to introduce transparency in military doctrines and postures, including nuclear weapon-related components, in spite of their legitimate security concerns and those of the military. While they have learned to be increasingly transparent about their activities, they must constantly try to strike a balance between, on the one hand, becoming more transparent and, on the other hand, their concern that transparency may undermine military effectiveness and national security. This balance is particularly delicate and difficult to achieve in the nuclear realm.

II. The context of the Non-Proliferation Treaty

Although the degree of application varies considerably, the principle of transparency has been introduced into the nuclear policies of the five legally recognized nuclear weapon states (NWS) over the past decade.[4] Moreover, transparency has become a key feature of international nuclear diplomacy and one of the benchmarks for judging nuclear policy.

The importance the international community attaches to nuclear transparency was highlighted at the 2000 Review Conference of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT). In the Final Document of the conference, the parties reached a consensus agreement on a list of 'practical steps' to be taken 'by all the nuclear-weapon States leading to nuclear disarmament in a way that promotes international stability, and based

[2] Prodi, R., 'Shaping the new Europe', Speech to the European Parliament in Strasbourg, 15 Feb. 2000, available at URL <http://europa.eu.int/comm/external_relations/news/02_00/speech_00_41.htm> (emphasis in original).

[3] NATO Heads of State and Government, 'The Alliance's Strategic Concept', Press Release NAC-S(99)65, 24 Apr. 1999, available at URL <http://www.nato.int/docu/pr/1999/p99-065e.htm>.

[4] In Article IX, paragraph 3, of the NPT a nuclear weapon state is defined as 'one which has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January, 1967'.

on the principle of undiminished security for all'.[5] Among these steps, the Final Document called for 'Increased transparency by the nuclear-weapon States with regard to the nuclear weapons capabilities and the implementation of agreements pursuant to Article VI and as a voluntary confidence-building measure to support further progress on nuclear disarmament'.[6] This complicated, two-fold commitment, made with caveats regarding 'international stability' and 'undiminished security', was probably less of an achievement than it might appear to be. Nevertheless, it was the first major commitment to nuclear transparency accepted by all five NWS in an international framework.

A number of groups were involved in raising the issue of nuclear transparency at the 2000 NPT Review Conference. The EU's Common Position for the conference can be credited with providing the main text of the statement of intent by the NWS. Among the 'substantive issues' deserving 'further consideration', it proposed 'increased transparency as a voluntary Confidence Building Measure to support further progress in disarmament'.[7] In addition, the so-called NATO-5 group (Belgium, Germany, Italy, the Netherlands and Norway) added further pressure for nuclear transparency in a working paper that detailed measures to complement the EU Common Position.[8] However, it was not a purely European idea, as illustrated by another working paper submitted to the conference, in which the New Agenda Coalition (NAC) suggested that 'the five nuclear-weapons States undertake, as early and interim steps . . . [t]o demonstrate greater transparency with regard to their nuclear arsenals and fissile material inventories'.[9]

[5] Final Document of the 2000 Review Conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2000/28, 24 May 2000, available at URL <http://www.iaea.org/worldatom/Press/Events/Npt/npt-2000.shtml>.

[6] Final Document (note 5). Article VI of the NPT states: 'Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control'. The complete text and comments on the treaty can be found at URL <http://www.state.gov/www/global/arms/treaties/npt1.html>.

[7] *Note verbale* dated 25 April 2000 from the Permanent Mission of Portugal to the United Nations addressed to the Secretariat of the 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Annex, Council Common Position of 13 April 2000, NPT/CONF. 2000/19, available at URL <http://disarmament.un.org/wmd/npt/2000doclist.htm>.

[8] 'States parties confirm the importance of measures aimed at increasing transparency with regard to nuclear arsenals. In particular, such measures could include a commitment by the nuclear-weapon States to provide periodically the aggregated numbers of warheads, delivery systems and stocks of fissile materials for explosive purposes in their possession. Nuclear-weapon States undertake to provide periodically within the framework of the strengthened review process a written account of the progress achieved towards the implementation of article VI of the Treaty and paragraph 4 (c) of the 1995 Principles and Objectives'. Working paper submitted by Belgium, Germany, Italy, the Netherlands and Norway, complementary to the European Union Common Position, for consideration in Main Committee I and Subsidiary Body, NPT/CONF.2000/MC.I/WP.7, 4 May 2000.

[9] The NPT 2000 Review Conference, New Agenda Coalition Working Paper, available at URL <http://www.ceip.org/programs/npp/nptnewagenda.htm>. The NAC is an influential group of like-minded states. It was launched in Dublin in June 1998. Joint Declaration by the Ministers for Foreign Affairs of Brazil, Egypt, Ireland, Mexico, New Zealand, Slovenia, South Africa and Sweden, Conference on Disarmament document CD/1542, 11 June 1998, available on the Acronym Institute Internet site at URL <http://www.acronym.org.uk/27state.htm>. Slovenia later withdrew from the New Agenda Coalition.

This commitment was not achieved easily. All the NWS had reservations, ranging from those requiring minor redrafting (the United Kingdom and the United States) to concrete substantive concerns or demands (France and Russia) to enduring opposition in principle (China). China's objection was never really addressed, since the chairman of the Chinese delegation issued a declaration at the end of the conference stating that, in his delegation's view:

> On the specific measures to reduce the danger of nuclear warfare and the so-called intermediate measures, the Chinese delegation believes that the most important priorities are: unconditional no-first-use . . . negative security assurance to all non-nuclear weapon states, withdrawing . . . all nuclear weapons deployed outside the borders of the nuclear weapon states and . . . nuclear umbrella [arrangements] and nuclear sharing. Any 'confidence building measures' divorced from these, will not be feasible. Further more, no relevant measure can be implemented without a necessary strategic stability environment.[10]

In spite of these objections, the 2000 NPT Review Conference established transparency as a permanent element of nuclear diplomacy, if not of the policies of the NWS.

One of the main purposes of this chapter is to provide a basis for assessing the prospects for implementation of the transparency commitment agreed at the conference and to consider the way forward. It examines the concepts which the NWS include under the notion of 'transparency' and then analyses the motives of the NWS in accepting or opposing particular nuclear transparency measures. The discussion goes beyond warheads and fissile material holdings to cover a wide range of nuclear activities. Finally, it examines the ways in which transparency is, or is not, applied.

It should be noted that this chapter does not evaluate the performance of the NWS in the field of transparency but rather analyses current policies and suggests improvements. It deals with the five NPT-defined NWS,[11] even though it is the belief of the author that any real transparency regime would also have to include the activities of the de facto NWS—India, Israel and Pakistan. A transparency regime would also have to be combined with a strengthened nuclear non-proliferation regime for the non-nuclear weapon states (NNWS). The chapter views the issue from the perspective of the NWS and outlines their efforts and concerns, while not ignoring their reluctance.

[10] 'Statement by Ambassador Hu Xiadi of the Chinese Delegation at the concluding meeting of the Sixth NPT Review Conference, 20 May 2000, NPT/CONF.2000/SR, available at URL <http://www.chinese-embassy.no/eng/3908.html>.

[11] The focus of this chapter is on the British and French cases; the Russian–US framework is treated in chapters 4 and 5, and the Chinese case is covered in appendix 3A.

III. Transparency, democracy and strategic/administrative culture

Transparency does not appear in a vacuum but is a by-product of much broader issues such as democracy and cultural values. The link between democracy and transparency is key and, on this point, the NWS are in very different situations. The more democratic societies are, the more open they tend to be. Therefore, transparency benefits from various factors that are typical for democratic societies, the most obvious of which are parliamentary control, respect for international norms, freedom of the press and academic research, and NGO activities. All of these factors help to develop transparency, even when governments are reluctant.

Political and strategic culture is a second major issue.[12] During most of the nuclear era, secrecy and deception were perceived as essential strategies to protect technological secrets, to protect key assets from pre-emptive strikes and to facilitate the achievement of strategic superiority. To a certain extent, this is still the case in most NWS. This persistent culture of secrecy could hinder progress towards greater transparency, even in democratic societies. In this regard, the weaker a country perceives itself vis-à-vis its potential opponents, the more it tends to emphasize secrecy as a strategic asset. Historically, the Soviet Union was a good example of a country playing secrecy as a strategic card. Today, secrecy is more important for the three smaller NWS than for Russia and the USA, which have highly redundant nuclear arsenals. Moreover, in China secrecy is seen as essential to compensate for a certain technological backwardness.

Bureaucratic culture is a third important issue. When a government has the traditional 'right' to manage national security issues with limited external control, it is in a position to determine on its own what level of transparency is acceptable. Countries with long traditions of centralized governments and strong administrations are therefore less likely to accept transparency. France is a good example in this regard, as are communist countries such as the former Soviet Union or contemporary China. The historical mandarin tradition of Chinese administration has a similar effect. By contrast, Anglo-Saxon countries have a well-established tradition of respect for citizens' 'rights to know' (e.g., the 1649 'May Day Agreement', which introduced parliamentary control over military activities in England and, more recently, the 1966 US Freedom of Information Act).[13]

[12] On strategic culture, see the series of articles in *International Security*, vol. 19, no. 4 (spring 1995), in particular the seminal article by Johnston, A. I., 'Thinking about strategic culture'. See also case studies such as Snyder, J., *The Soviet Strategic Culture: Implications for Nuclear Options,* R-2154-AF (Rand Corporation: Santa Monica, Calif., 1977); Gray, C., *Nuclear Strategy and National Style* (Hamilton Press: Lanham, Md., 1986); and Grand, C., *A French Nuclear Exception?*, Occasional Paper no. 38 (Henry L. Stimson Center: Washington, DC, Jan. 1998).

[13] An Agreement of the Free People of England (May Day Agreement), 1 May 1649, available at URL <http://www.constitution.org/eng/agreepeo.htm>; and The Freedom of Information Act, 5 USC §552, as

Transparency in nuclear weapon complexes is highly dependent on historical traditions and administrative habits. For example, it took the tremendous changes in the former Soviet Union and years of glasnost to open the closed Soviet nuclear cities, but democratization could not suddenly break the habits inherited from 50 years of Soviet nuclear history. Similarly, in democratic countries in which parliamentary control over military activities has been traditionally weak or limited, there is no proper basis for external transparency. When military or nuclear establishments do not have to demonstrate internal transparency to democratically elected leaders or parliamentarians, they are likely to be more suspicious of—and reluctant to accept—external transparency.[14]

IV. Nuclear transparency and security

As is the case for other forms of arms control, disarmament and confidence-building measures (CBMs), the main objection to transparency is that it adversely affects national security. It is always difficult to convince governments, and military establishments in particular, that transparency can enhance national security rather than weaken it. Indeed, many experts acknowledge that these concerns are not without merit in the nuclear field.

Historically, nuclear secrecy has been primarily a non-proliferation tool. In the USA, for example, the McMahon Atomic Energy Act of 1946 codified nuclear secrecy into law by prohibiting the 'exchange of information with other nations with respect to the use of atomic energy'.[15] Accordingly, the proponents of a particular transparency measure need to demonstrate that it does not inadvertently disclose militarily useful information to would-be proliferators. This is particularly true for all the declassification measures and international on-site inspections (including those of dismantled facilities or weapons) that might result in the disclosure of sensitive information. However, attitudes towards nuclear secrecy evolved in a radical manner in the 1990s, at least in some NWS. The unprecedented Openness Initiative of US Secretary of Energy Hazel O'Leary can in this context be seen as a major policy shift, even though its scope seems to have been subsequently restricted—precisely in order to address national security concerns.[16]

amended by Public Law No. 104-231, 110 Stat. 3048, available at URL <http://www.usdoj.gov/oip/foia_updates/Vol_XVII_4/page2.htm>.

[14] The distinction between internal and external forms of transparency is further developed in chapter 2 in this volume.

[15] On the role of the McMahon Act in imposing nuclear secrecy see Goldschmidt, B., *Le complexe atomique* [The atomic complex] (Paris: Fayard, 1980), pp. 96–99; and Newhouse, J., *The Nuclear Age: From Hiroshima to Star Wars* (Michael Joseph: London, 1989), pp. 55–56. Interestingly, the McMahon Act is best known for imposing civil control over the US nuclear programme, a form of 'internal transparency'. It prohibited even peaceful cooperation until the Eisenhower Administration's Atoms for Peace plan led to its amendment. See, e.g., URL <http://www.iaea.or.at/worldatom/About/Profile/atoms.html>.

[16] For more about the Openness Initiative see the statement of 15 Jan. 1997 by US Secretary of Energy O'Leary in DOE Press Release R-97-003, in *Disarmament Diplomacy*, no. 12 (Jan. 1997), pp. 38–39. For

The protection of robust deterrence capabilities is another important and legitimate goal for the NWS. In certain cases transparency measures could disclose information about, or expose weaknesses in, force postures or technology, which could be exploited by potential adversaries. For example, the NWS tend to view the release of the exact capabilities or location of nuclear weapons as a security risk. China explicitly put forward this argument at the 2000 NPT Review Conference when it refused to allow weapon transparency to apply to China. France and the UK also face this dilemma. However, since they are close allies of the USA, they obviously do not perceive US high-precision conventional weapons or missile defence plans in the same way as China does, that is, as having the potential to undermine nuclear deterrence. Clearly, then, the global security environment and the threat perceptions of individual NWS must be taken into account when assessing their willingness to accept transparency. In this context, the development of missile defences is likely to have a negative impact on transparency since countries that feel threatened could respond by refusing to disclose any information about their forces in order to complicate the task of the missile defence system. This applies to both China and Russia.

Finally, progress in nuclear transparency is highly dependent on relations between the NWS. It was very limited until the late 1980s. The achievements made in the early 1990s within the Russian–US framework would have been unthinkable at any point during the cold war. At that time, the transparency measures applied by the NWS were limited to Soviet–US bilateral exchanges on nuclear delivery vehicles and to information provided by national technical means (primarily space-based intelligence). The higher the level of tension in political relations between the NWS, the less likely it is that they will enact new measures, as current Chinese–US (or, conversely, Russian–US) relations demonstrate. This is somewhat of a paradox, since transparency is most useful in times of international tension.

It is important to note that the NNWS see the security concerns posed by nuclear transparency from a different perspective. For them, transparency is a means of enhancing their security in that it provides assurances about the nuclear policies of the NWS. While most of the NNWS acknowledge proliferation-related concerns as legitimate, they otherwise tend to favour enhanced transparency in all of the fields described below. It is therefore perhaps not surprising that most of the recent proposals for transparency have come from either the NNWS or mixed groupings, such as the EU, the NATO-5 and the New Agenda Coalition.[17]

an official update of the results of this declassification policy, see US Department of Energy, Office of Declassification, *Restricted Data Declassification Decisions, 1946 to the Present,* RDD-7 (1 Jan. 2001), and the database available at URL <http://www.osti.gov/opennet>. For a congressional assessment of government secrecy policy see Moynihan Commission, *Report of the Commission on Protecting and Reducing Government Secrecy 1997*, Senate Document 105-2, Pursuant to Public Law 236, 103rd Congress (US Government Printing Office: Washington, DC, 1997), especially appendix A, 'Secrecy: a brief account of the American experience', all available at URL <http://www.access.gpo.gov/congress/commissions/secrecy/index.html>.

[17] Chapter 6 in this volume deals extensively with the concerns of the non-nuclear weapon states.

V. A typology of the transparency efforts of the NWS

Having noted the causes of the reluctant, ambivalent or often hostile approaches of the NWS to transparency, it is analytically useful to establish a typology of their transparency efforts, or at least of those policies claimed to be for the promotion of transparency.[18] The typology below ranks possible transparency measures in terms of their political and technical feasibility, beginning with the easiest steps and proceeding to the more difficult ones.

Historical transparency

Introducing transparency in past activities is the easiest approach because the risks are limited. It is also an efficient way to begin to develop a transparency culture. Nevertheless, it requires that past activities have been properly recorded and that disclosure does not lead to the release of sensitive information or the opening of sensitive debates.

Nuclear history

The opening of archives facilitates historical research on the political and scientific aspects of nuclear programmes, which can dispel national nuclear myths and help to correct misperceptions. The international Nuclear History Program (NHP)[19] and the National Security Archive at George Washington University[20] are good examples of historical research projects that have had a policy impact. However, such efforts have focused primarily on the nuclear history of France,[21] the UK, the USA, NATO and—to a lesser extent—the USSR.[22] Comprehensive accounts drawing on regular and archive-based historical investigations are still lacking for China.[23]

[18] See appendix 3A in this volume for an alternative typology.

[19] The NHP was established in 1986 as a joint effort by Harvard University and the Stiftung für Wissenschaft und Politik and involves British, French, German and US historians. In addition to the international effort, the 4 national groups have published numerous books and papers.

[20] For information about the National Security Archive see its Internet site, URL <http://www.gwu.edu/~nsarchiv>, and document collections on microfiche and CD-ROM.

[21] For examples of recent research on the French programme that has benefited from this opening of archives see Mongin, D., *La bombe atomique française, 1945–1958* [The French atomic bomb, 1945–1958] (Bruylant/LGDJ: Brussels, 1997); Vaïsse, M. (ed.), *La France et l'atome: études d'histoire nucléaire* [France and the atom: studies of nuclear history] (Bruylant: Brussels, 1994); and Bendjebbar, A., *Histoire secrète de la bombe atomique française* [The secret history of the French atomic bomb] (Le Cherche Midi Editeur: Paris, 2000).

[22] See, e.g., the findings on Soviet nuclear strategy of the Parallel History Project on NATO and the Warsaw Pact (PHP), at URL <http://www.isn.ethz.ch/php>.

[23] For what are still the best accounts of the Chinese nuclear programme see Lewis, J. W. and Xue Litai, *China Builds the Bomb* (Stanford University Press: Stanford Calif., 1988); and Lewis, J. W. and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernization in the Nuclear Age* (Stanford University Press: Stanford Calif., 1994).

Nuclear testing

After the NWS halted nuclear testing, a wealth of information was disclosed about past explosions, including previously unknown failures and accidents. The release of such information seems to be acceptable as long as it does not benefit the nuclear weapon programmes of the threshold states. France, Russia, the UK and the USA have now provided fairly detailed historical accounts of their testing programmes (in terms of the numbers and yields of nuclear explosions and the purposes of the tests),[24] and in 1994 the USA began to release more information about its nuclear testing programme.[25] In August 1995 France released a detailed list of its nuclear tests as part of a transparency effort when it conducted a final series of tests.[26] Much more is now also known about Soviet tests. The Soviet Ministry of Atomic Energy (Minatom) released the first list of tests in 1990, and more has been disclosed since then.[27]

Before the numbers of nuclear tests were officially disclosed, many mistakes appeared even in expert publications. For example, until the French Government released a detailed account of the 204 nuclear tests (including 12 safety tests) it conducted from 1960 to 1991, outside estimates varied from 173 (a Swedish estimate) to 182 (a Soviet estimate) and 192 (the estimate of the Natural Resources Defense Council, NRDC). This indicates the difficulty of determining numbers of tests, not to mention the details of the tests. In December 1993 US Secretary of Energy O'Leary revealed 204 previously undisclosed US nuclear tests, including one conducted in 1964 jointly with the UK.[28]

Nuclear incidents

The disclosure of past nuclear weapon-related incidents is a transparency measure that most nuclear establishments are reluctant to accept, since it may reveal

[24] For a general account and a comparison see Natural Resources Defense Council (NRDC), 'Nuclear Notebook: Known nuclear tests worldwide, 1945–98', *Bulletin of the Atomic Scientists*, vol. 54, no. 6 (Nov./Dec. 1998); and NRDC, 'Nuclear Notebook: Known nuclear tests worldwide, 1945–95', *Bulletin of the Atomic Scientists*, vol. 52, no. 3 (May/June 1996), both available at URL <http://www.bullatomsci.org/issues/nukenotes/nukenote.html>.

[25] See US Department of Energy (DOE), Nevada Operations Office, *United States Nuclear Tests July 1945 through September 1992*, DOE-NV-209-REV 15, Dec. 2000. The most recent DOE publications on nuclear testing are available at URL <http://www.nv.doe.gov/news&pubs/publications/historyreports/default.htm>. Most of the US information was first disclosed in 1993–94.

[26] Service d'Information et de Relations Publiques des Armées, *Propos sur les essais nucléaires* [Remarks on nuclear tests], Paris, 1995; and, for more details, le Baut, Y. (ed.), *Les essais nucléaires français* [French nuclear tests] (Bruylant: Brussels, 1996). The volume by le Baut includes several papers by key witnesses and actors. This followed a speech by President François Mitterrand in 1994, in which he stated that France had carried out 192 nuclear tests. 'Intervention de Monsieur François Mitterrand sur la politique française de dissuasion' [Statement by Mr François Mitterrand on French deterrent policy], Palais de l'Elysée, 5 May 1994.

[27] Natural Resources Defense Council (NRDC), 'Nuclear Notebook: Soviet nuclear testing, August 29, 1949–October 24, 1990', *Bulletin of the Atomic Scientists*, vol. 54, no. 3 (May/June 1998), URL <http://www.bullatomsci.org/issues/nukenotes/nukenote.html>; and Mikhailov, V. N. (ed.), *Catalog of Worldwide Nuclear Testing* (Begell-Atom, LLC: New York, 1999).

[28] Institute for Defense and Disarmament Studies (IDDS), *Arms Control Reporter* (IDDS: Brookline, Mass.), sheet 608.B.285, Mar. 1993; and Ferm, R., 'Nuclear explosions, 1945–93', *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), p. 309.

weaknesses and shortcomings, thereby strengthening anti-nuclear movements. This is particularly true of the nuclear incidents that have taken place beyond national borders. At the same time, it can be argued that such disclosures underscore, at least in the West, how safe and reliable nuclear weapon practices are, given the limited numbers of incidents that have occurred. There is in fact a growing tendency for the NWS to become more transparent about past incidents in response to pressure from historians and the media.

Production of weapon-grade fissile materials

It is widely believed that none of the five NPT-defined NWS currently produces fissile material for military purposes, although China has never officially confirmed that it has stopped production. By providing detailed accounts of their past production of plutonium or highly enriched uranium (HEU), the NWS effectively disclose the potential sizes of their stockpiles of both material and warheads. So far, only the UK and the USA have released details about past production of plutonium. The US figures were released in February 1996 and were an essential part of the Openness Initiative.[29] The British figures were released in 2000.[30] In general, it is technically easier to provide accurate accounts of plutonium production than of HEU production.[31]

Given the practices of nuclear weapon establishments, calculating past production of fissile material is often quite complicated, especially production in the early stages of nuclear programmes. As the British and US experiences have demonstrated, the further a researcher goes back in history, the more difficult it is to produce a detailed account. This can be explained by such factors as a lack of archives, poor accounting at the time of production and the retirement of key personnel.

Production of nuclear weapons

There has been only limited disclosure of information about nuclear weapon production. The USA has declassified certain aggregate characteristics of its stockpile (the total yield and the number of weapons retired) from 1945 to 1994, as well as the total number of weapons produced from 1945 to 1961. In addition, congressional records and declassified material have helped organizations such as the NRDC to establish fairly accurate accounts of past weapon production. Little information has been released about specific weapons, largely

[29] US Department of Energy (DOE), *Plutonium: The First 50 Years*: *United States Plutonium Production*, *Acquisition, and Utilization from 1944 through 1994*, DOE/DP-0137 (DOE: Washington, DC, Feb. 1996), available at URL <http://www.osti.gov/osti/opennet/document/pu50yrs/pu50y.html>.

[30] British Ministry of Defence (MOD), *Report on the Role of Historical Accounting for Fissile Material in the Nuclear Disarmament Process, and on Plutonium for the United Kingdom's Defence Nuclear Programme* (MOD: London, Apr. 2000), available at URL <http://www.mod.uk/publications/nuclear_weapons/accounting.htm>.

[31] For a discussion of some of the difficulties see Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997), pp. 83–84.

because of concerns about disclosing sensitive design information that might assist would-be proliferators.

Transparency in current policies

Transparency in current policies is the most interesting and most beneficial kind of transparency, as well as the most difficult because of the security concerns involved. There are large differences in the approaches of the NWS, as the 2000 NPT Review Conference showed. Some of the areas in which transparency might be achieved are discussed below, ranging from the easiest to the most difficult.

National disarmament efforts

In the context of disarmament, transparency is related to the principle of public accountability and can be seen as a CBM. Three NWS (France, the UK and the USA) routinely produce brochures for international events, such as the 2000 NPT Review Conference, in order to publicize their efforts in the field of disarmament.

National events such as a major nuclear policy speech can also provide opportunities for transparency. The 1994 speech of the French president is an extraordinary example: President Mitterrand provided details about the number of French nuclear weapon delivery systems, the number of nuclear tests France had conducted and the approximate number of available nuclear warheads ('about 500').[32] Similarly, the publication of a defence White Paper can provide an opportunity for increased transparency, as the 1998 British Ministry of Defence Strategic Defence Review (SDR) demonstrated.[33] While such efforts may seem to be only exercises in public communication, they are in fact real transparency measures.

The military is sometimes reluctant to acknowledge the level of force reductions that have been carried out, for security or political reasons, and governments may be tempted, for domestic political reasons, not to portray a particular measure as a step towards disarmament. Nonetheless, even a tightly controlled release of information can be seen as a form of transparency.

Doctrines

Probably the most questionable form of transparency has to do with nuclear doctrines because they are subject to change and may also be part of a deception strategy. They are by definition theoretical and impossible to verify. It is

[32] Mitterrand (note 26). This speech remains one of the most comprehensive descriptions of the French nuclear arsenal.

[33] British Ministry of Defence (MOD), *Strategic Defence Review* (MOD: London, 1998), available at URL <http://www.mod.uk/issues/sdr/wp_contents.htm>.

therefore difficult to argue, as some in China do, that a no-first-use declaratory policy is a major transparency measure.

Nonetheless, the publication of nuclear doctrines or statements on doctrines can result in concrete security benefits for both the NWS and the NNWS. Similarly, serious and genuine exchanges on nuclear policies between the NWS or their alliances can have positive effects, as suggested by the recent limited exchanges between NATO and Russia. By reducing the risk of misunderstanding and miscalculation, transparency in doctrines can enhance stability and predictability in nuclear relations and reduce the danger of the unintended use of nuclear weapons.

Bilateral and multilateral arms control: on-site inspections and data exchanges

As nuclear arms control and disarmament have progressed, the NWS have learned to communicate information about their efforts to both the international community and their potential adversaries. In this context, they have developed reassurance policies and verification mechanisms. Some bilateral agreements have included an obligation to disclose the number of dismantled nuclear weapons and to demonstrate the effective destruction of weapon systems. However, at this stage, not all the NWS have experience with arms control verification, since the three smaller NWS are not involved in mutual reduction processes. Moreover, not all of them have exchanged data or accepted inspections. By signing the 1996 Comprehensive Nuclear Test-Ban Treaty (CTBT), all the NWS have accepted the principle of on-site inspections as a means to verify the test ban. The most significant achievement in nuclear transparency is the acceptance of on-site inspections under the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty) and the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty), in a bilateral framework, and under the CTBT, in a multilateral framework.

Information about nuclear weapon holdings has been released not only to parties to treaties but also to the international community. For example, the data on the number of treaty-accountable delivery vehicles held in each of the parties' inventories, which are exchanged every six months under the terms of START I, are subsequently made publicly available. Within the framework of the Cooperative Threat Reduction programme and material protection, control and accounting (MPC&A) agreements, there have been inspection visits to many sensitive nuclear sites, including warhead storage sites. Only warhead production facilities are off-limits to inspectors.[34]

[34] For further discussion of the Cooperative Threat Reduction programme see chapters 4 and 5 in this volume.

Existing and closed nuclear facilities

Opening facilities to foreign visitors or inspectors is a transparency measure, as the Russian–US experience has demonstrated. It is also a practice which creates a more symmetrical nuclear relationship between the NNWS, which are under International Atomic Energy Agency (IAEA) full-scope safeguards, and the NWS, which are not. The nature of the visit or the inspection procedure, however, is an essential element: the distinction between genuine transparency and restricted, monitored access must be clear.

France and the UK have a long experience of nuclear inspections of nearly all of their civilian nuclear facilities through the European Atomic Energy Community (Euratom) safeguards system. The UK (since 1978) and France (since 1981) have accepted safeguards as part of a trilateral process involving the IAEA and Euratom. Moreover, in 1998 they signed two additional protocols, allowing enhanced safeguards.[35] In the case of the UK, fissile material production sites formerly off-limits for safeguards (the Capenhurst A3 enrichment plant and the Chapelcross and Calder Hall plutonium production reactors) were put under Euratom safeguards after production for weapon purposes was stopped. France also opened its South Pacific test sites to visits by independent experts. There were visits by international experts in 1982, 1983 and 1987, which were followed by public reports on the ecological and geological status of these former test sites. In addition, the French Government invited a board of experts led by the IAEA to make inspections from 1996 to 1998, which led to the publication in May 1998 of a 2000-page scientific study.[36]

Fissile material holdings

The UK and the USA have released information about their fissile material holdings, while Russia has been more restrictive. If a Fissile Material Cut-off Treaty (FMCT) ever comes into force, it might eventually include provisions for increasing transparency in fissile material stockpiles.[37]

The international community has demonstrated considerable interest in this form of transparency, in contrast to the reluctance of China and France. The French Government does not disclose information related to fissile material holdings in the military realm (except in the case of the closure and dismantling of production facilities).[38] Its position is based on the argument that it has no

[35] For the full text of the additional protocols applicable to France and the UK see the EU Internet site at URL <http://europa.eu.int/comm/energy/nuclear/safeguards.htm>.

[36] IAEA, *Study of Radiological Situation at Atolls of Mururoa and Fangataufa* (IAEA: Vienna, 1998); and IAEA, 'Study of radiological situation at atolls of Mururoa and Fangataufa', Press Release PR 1998/4, 29 May 1998, URL <http://www.iaea.org/worldatom/Press/P_release/1998/prn0498.shtml>. See also *IAEA Newsbrief*, vol. 13, no. 3 (July/Aug. 1998).

[37] On the potential role of an FMCT, see Grand, C., 'A Fissile Material Cut-off Treaty and the future of nuclear arms control', ed. J. Cirincione, *Repairing the Regime: Preventing the Spread of Weapons of Mass Destruction* (Routledge: New York, 2000), pp. 233–46. The current FMCT mandate covers only the monitoring of production facilities. See also chapters 5 and 10 in this volume.

[38] President Jacques Chirac, Television interview with Anne Sinclair and Alain Duhamel, 22 Feb. 1996, URL <http://www.elysee.fr/cgi-bin/auracom/aurweb/search/file?aur_file=discours/1996/TV220296.html>.

weapon-usable fissile material in excess of military needs. China has not provided any statements on the matter, not even to confirm or deny that production continues. Both countries can therefore be expected to face increasing international pressure on the issue of fissile material holdings.

Nuclear weapon holdings and capabilities

Nuclear transparency is most developed with respect to weapon holdings and capabilities. With the exception of China, all the NWS have made statements or issued documents providing some details of their nuclear weapon holdings or have released information on the basis of which these holdings can be estimated with some accuracy. However, there is no common form for this information, which complicates comparative assessments. Furthermore, no NWS has provided a comprehensive, detailed description of its nuclear arsenal. The technical details of the yield, range and operational status of existing weapon systems are also highly classified.

Russian and US disclosures take place primarily as part of formal agreements (e.g., START I) and reveal the numbers of treaty-accountable weapons. These focus on strategic nuclear weapons, which means that the information is primarily about the delivery vehicles; very limited information is available on the numbers of warheads. An entire class of weapons—tactical nuclear weapons—is not accounted for in these disclosures and weapons held under various reserve categories are almost always omitted from official accounts.

The British SDR produced a fairly precise figure for the British stockpile: 'fewer than 200 operationally available nuclear warheads'.[39] It stated that there are a maximum of 48 warheads deployed on each of the UK's four Trident submarines. It also stated that 58 Trident II (D-5) submarine-launched ballistic missiles are earmarked for the British inventory. The precise meaning of 'operationally available' has nevertheless led to debates about the exact numbers in the British stockpile.

In a much less publicized, less organized, and more modest way, France has provided fairly detailed figures for its nuclear forces, starting with the 1994 speech by Mitterrand, continuing with the 1996 and 2001 statements by Chirac and including the legal documents attached to the five-year procurement laws and annual defence authorization budgets.[40] The official Ministry of Defence

[39] British Ministry of Defence (note 33).

[40] For recent French parliamentary documents see *Avis no. 3323 présenté au nom de la Commission de la défense nationale et des forces armées*, sur le Projet de Loi de finances pour 2002 (no. 3262), tome II, Défense, dissuasion nucléaire par M. René Galy-Dejean; *Avis no. 2627 présenté au nom de la Commission de la défense nationale et des forces armées*, sur le Projet de Loi de finances pour 2001 (no. 2585), tome II, Défense, dissuasion nucléaire par M. René Galy-Dejean; and *Projet de Loi relatif à la loi de programmation militaire pour les années 2003–2008*, no. 3255, déposé le 31 juillet 2001. The Internet site of the French Parliament is URL <http://www.assemblee-nationale.fr>. For a comprehensive study based on existing documents see Barillot, B., *Audit atomique: le coût de l'arsenal nucléaire français 1945–2010* [Atomic audit: the cost of the French nuclear arsenal 1945–2010] (Centre de documentation et de recherche sur la paix et les conflits: Lyons, 1999).

brochure for 2000 focuses on delivery vehicles and specifies a reduction from more than 200 to about 100.[41]

One good benchmark for judging transparency in weapon holdings is the degree of precision and certainty which non-governmental analysts assign to their published estimates.[42] Because China is restrictive in releasing public information on its arsenal, analysts tend to assign a high degree of uncertainty to their estimates. Information about the arsenals of the de facto NWS is also very limited. These observations may point to a certain relationship between the level of advancement of a nuclear programme and nuclear transparency.

Ways for the NWS to apply nuclear transparency

Unilateral declarations and actions

The most common form of transparency, in particular for the smaller NWS, is unilateral declarations and actions. In these instances transparency is a national political choice, with the potential involvement of external actors (e.g., IAEA monitoring teams and visits by foreign inspectors). Since 1997, the British Labour Government has made transparency a distinct feature of its nuclear policy, thus taking the lead among the NWS in efforts to move from nuclear secrecy to nuclear accountability. While a cultural shift towards openness has taken place in the UK, nuclear secrecy continues to be viewed as a major security asset in China and France. France is less inclined to make transparency a central element of its nuclear posture for cultural and political reasons, and China claims that the small size and less survivable nature of its arsenal make concrete transparency measures undesirable.

Bilateral agreements, treaties and nuclear cooperation

The implementation of transparency by means of bilateral agreements, treaties and nuclear security cooperation has been largely limited to Russia and the USA. Although this has not always been satisfactory from the perspective of the rest of the world, it has obviously been necessary, given the special nature of the relationship between the two major nuclear weapon powers and the size of their arsenals. In certain cases, there is a potential for Russia and the USA to contribute to the extension of transparency by providing more details about the bilateral processes in which they have been and are engaged. However, the trend seems to be going in the opposite direction. During and after the November 2001 summit meeting between US President George W. Bush and Russian President Vladimir Putin, the approach of the US Administration has been to emphasize flexible, reversible, unverified and non-treaty-based nuclear reduc-

[41] French Ministry of Defence, *Maîtrise des armements*, *désarmement et non-prolifération: l'action de la France* [Arms control, disarmament and non-proliferation: French policy] (Documentation française: Paris, Apr. 2000), p. 39.

[42] See estimates in, e.g., the *SIPRI Yearbook*, the NRDC 'Nuclear Notebook' section of *The Bulletin of the Atomic Scientists* and *The Military Balance* of the International Institute for Strategic Studies.

tions.[43] This seems to have become the norm today. In such a context, transparency is a secondary consideration. This is especially true for third parties (both NWS and NNWS), which may perceive that they are losing the transparency benefits which the START process once provided.

Multilateral agreements involving only the NWS

A less explored option is for NWS to make progress in transparency by entering into multilateral agreements with other NWS. This option would offer mutual guarantees in terms of non-proliferation and would also be useful in fostering trust and promoting further arms reductions. However, there is a risk that it would create frustration and potential mistrust among the excluded NNWS if it were to become the main transparency instrument.

So far, the three smaller NWS have been reluctant to engage in a binding arms reduction process owing to the relatively small size of their arsenals. It could be argued that they have a lot to gain from encouraging and participating in CBMs or even a commitment not to increase the size of nuclear arsenals. These measures would be welcomed by the NNWS and would facilitate further bilateral or unilateral cuts by the two great nuclear weapon powers. In this regard, British and French transparency has unilaterally provided enough information to offer such reassurance.

In contrast, China's nuclear modernization is likely to be of increasing concern to Russia and the USA, as long as its end result is not known. Although some analysts have claimed that China is the only NWS that is expanding its nuclear arsenal, it is not the only NWS that is modernizing its forces. To a certain extent, nuclear force modernization is under way in all the NWS. However, China is the only country in which the lack of transparency does not allow a certain degree of predictability about its nuclear force posture (see also appendix 3A).

Other multilateral agreements

A number of multilateral transparency tools exist (IAEA safeguards) or are under development (the Comprehensive Nuclear Test-Ban Treaty Organization). However, the real test is likely to be the implementation of an FMCT, if it ever enters into force with an adequate verification regime. Because an FMCT could bring an unsurpassed degree of transparency to fissile material holdings, it is at the heart of efforts to establish a transparency regime. Even without one, an FMCT would open previously closed nuclear facilities to inspections.

[43] For an account of the discussions in late 2001 between presidents Bush and Putin on nuclear reductions see Kile, S., 'Ballistic missile defence and nuclear arms control', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 515–16. The text of the Russian–US Strategic Offensive Reductions Treaty, which codified the deep reductions announced during the Crawford, Texas, summit meeting and was signed on 24 May 2002, is available at URL <http://www.state.gov/t/ac/trty/10527.htm>.

VI. Conclusions

1. *The connection between transparency and security is a key consideration for the NWS.* While the NNWS place a high priority on the demand for transparency, the NWS have demonstrated their reluctance to enter into transparency arrangements which in their view are ineffective or dangerous in security terms. Attempts to make progress in this area must therefore present solid arguments for any security benefits that can be expected from increased transparency in its various forms.

Transparency cannot be disconnected from strategic realities. As was the case for other arms control-related measures, the progress in nuclear transparency in the 1990s was possible because of the relaxation of tensions following the end of the cold war. In times of tense relations among the leading powers, the lack of confidence makes progress unlikely because security measures and secrecy are viewed as more useful than transparency efforts. In such strategic contexts, the security benefits that can be expected from increased transparency tend to be ignored.

2. *Transparency efforts constitute a learning process in which confidence grows and facilitates further steps.* As with arms control in general, the implementation of transparency policies is a learning process in which nuclear establishments need to proceed gradually in order to better understand the possible benefits both for themselves and for international security. The risks involved will also become clearer—as will the steps necessary to limit them. Once a particular transparency measure has been successfully implemented, further efforts can more easily be envisaged.

Nuclear-related matters have traditionally been part of a culture of secrecy. It is therefore understandable that civilian and military nuclear establishments are reluctant to accept any departure from past practices. Transparency is a field in which perceptions matter greatly; if a transparency measure is perceived to affect national security adversely, the likelihood of its implementation falls sharply. Moreover, if the NWS do not share the objective or policy of transparency, they will perceive transparency efforts as counterproductive because nuclear imbalances tend to create instabilities in other areas. Finally, as some secrecy is likely to remain a legitimate characteristic of nuclear policy, transparency can be perceived as a dangerous slippery slope and engagement in it as undesirable.

3. *The NWS cannot be viewed as a single entity as far as transparency is concerned.* The differences in nuclear culture as well as the size and organization of their nuclear forces explain the different approaches towards transparency taken by the five declared NWS. The two big nuclear powers—Russia and the USA—are in a special category of their own, for reasons related to the role of their bilateral nuclear dialogue. While they share general concerns about the size of arsenals and nuclear complexes, the three smaller NWS have different national policies, ranging from the UK's genuine interest in providing a high

degree of nuclear transparency, including transparency in the difficult field of fissile material and warhead holdings, to the Chinese view of transparency as being contrary to its national security interests. France is probably less reluctant than China to implement transparency measures but more concerned than the UK about the negative side effects of these measures. For similar reasons, the de facto NWS are unlikely to accept transparency.

4. *Because transparency policies are so different, a minimum common language is needed, if only to acknowledge that there are different approaches.* Assuming that it is acknowledged, at least for now, that such national differences are legitimate, further work is needed to develop a minimum common language among the NWS in order to avoid misunderstandings and, at a later stage, to design measures applicable to all the NWS.

Transparency is not a panacea for the security problems of the nuclear age. For a variety of reasons related to the ongoing changes in international security, ranging from the proliferation of nuclear, biological and chemical weapons to terrorists and from the development of missile defences to a certain re-nuclearization of strategic relations, the trend towards increasing nuclear transparency observed in the 1990s might be facing a pause or even a reversal. The detailed study of political and technical measures to promote transparency should nevertheless be continued, precisely because there are genuine security benefits that can be expected if further progress in nuclear transparency is made. Transparency should therefore not be regarded as a fashionable policy. If it is handled properly, it has the potential to be a defining principle for the future of nuclear policies.

Appendix 3A. China and nuclear transparency

Li Bin

I. Introduction

One approach to making nuclear weapons less threatening is to promote nuclear transparency. If the nuclear weapon states (NWS) provide publicly available information about the status of their nuclear weapons and if transparency is managed appropriately, the suspicions, fears and miscalculations among states and citizens about the use of nuclear weapons could be reduced. At the same time, the NWS consider some of this information as highly sensitive because of the mass destruction effects of nuclear weapons. They have to be very careful in drawing the line between transparency and secrecy in nuclear weapon activities. In general, China supports the concept of transparency in armaments but also calls for the thorough examination of different transparency measures and different treatment of them, depending on their implications for China's security.

> China supports appropriate and feasible transparency measures in armaments in a bid to promote mutual trust between states and regions and to enhance world peace, security and stability. It should be emphasized that transparency in armaments is [a] means rather than [an end]. Under the current international situation, no country can support or achieve absolute transparency in armaments. When and at what stage a certain country can and should undertake what transparency measures must be guided by the basic principle of assured security for all states. Countries can define specific transparency measures consistent with their national or regional situation and requirements on the basis of voluntary choice or through consultations according to their specific surroundings and political, military and security conditions.[1]

The Chinese position on nuclear transparency follows these principles. This appendix explores the security considerations and other factors that shape China's policy on different approaches to nuclear transparency.

Five kinds of nuclear weapon transparency can be discerned: transparency in nuclear strategy, qualitative transparency, quantitative transparency, clarification of nuclear activities and acceptance of site visits. Transparency in nuclear strategy means that a state provides information about its nuclear posture and strategy. Qualitative transparency means that a state provides information about its types of nuclear weapons, for example, on its possession of nuclear or thermonuclear warheads and on the major delivery systems for them. Quantitative transparency implies that a state provides data on the number of nuclear weapons in its possession or data from which such information could be

[1] Foreign Ministry of the People's Republic of China, 'Transparency in armaments', URL <http://www.fmprc.gov.cn/eng/5382.html>.

derived. With regard to the fourth kind of transparency, some nuclear or nuclear-relevant activities can be misinterpreted by other states and therefore cause dangerous reactions. Clarification of nuclear activities removes suspicions by explaining the purpose and the nature of these activities and/or by providing evidence that the explanations are accurate. Finally, the NWS occasionally allow foreign visitors to enter some of their nuclear sites, including their testing, production, research and launch sites. The acceptance of site visits can help other states to learn about the nuclear status of a state and thereby avoid overestimations of its nuclear capability. On the basis of their different implications for security, China takes different approaches to the five kinds of transparency.

II. Chinese attitudes towards nuclear transparency

China supports transparency in nuclear strategy. It clearly defined the principles of its nuclear strategy in 1964, when it conducted its first nuclear test explosion: 'The Chinese Government hereby solemnly declares that China will never at any time or under any circumstances be the first to use nuclear weapons'.[2] This no-first-use commitment is not just a diplomatic gesture; it is a statement of domestic defence policy that has regulated the development and evolution of China's nuclear arsenal since the beginning of its nuclear programme. The declaration of China's nuclear strategy based on a no-first-use commitment has helped the rest of the world to understand the nature of China's nuclear force. China has also declared some of the characteristics of its nuclear force which result from its no-first-use policy. These include keeping the nuclear force small and maintaining deterrence as its sole function.[3] The first characteristic indicates that China will not develop a first-strike capability, which would rely on a large number of nuclear weapons. The second characteristic limits the categories of deployed nuclear weapons, meaning that China does not deploy nuclear weapons that are suitable for war-fighting but not for deterrence. Estimates provided by outside experts about the quantity and categories of Chinese nuclear weapons corroborate these statements.[4] In the early period of nuclear development in China, the no-first-use declaration enhanced China's security by reducing the incentives of the former Soviet Union and the United States to launch a pre-emptive strike against China. China's firm commitment to no-first-use still plays an important role in maintaining nuclear stability.

In addition to its mission and size, China's nuclear force has other characteristics that are consistent with a no-first-use policy. A Chinese journal described

[2] 'Chinese government statement on the complete prohibition and total destruction of nuclear weapons', available on the official Internet site of the Chinese Ministry for Foreign Affairs, URL <http://www.fmprc.gov.cn/eng/5741.html>.

[3] Chinese Ministry of Defence, *China's National Defense 2000* (Information Office of the State Council of the People's Republic of China: Beijing, Nov. 2000), p. 2, available at URL <http://www.nti.org/db/china/engdocs/wpnd2000.htm>.

[4] See estimates in, e.g., the *SIPRI Yearbook*, available at URL <http://projects.sipri.org/nuclear/index.html>, and the NRDC 'Nuclear Notebook' section of *The Bulletin of the Atomic Scientists*, available at URL <http://www.bullatomsci.org/issues/nukenotes/nukenote.html>.

a military exercise in which the Chinese Second Artillery simulated launching a retaliatory strike several days after a simulated nuclear attack on China.[5] This indicates that China's nuclear weapons are not on high alert, in contrast to normal Russian and US practice. A delayed nuclear response policy makes an accidental launch of Chinese nuclear weapons impossible.

China has not disclosed data with regard to its nuclear strategy because its nuclear deterrence relies on 'quantitative ambiguity', as discussed below.

China often releases information about the characteristics of its nuclear forces. China has announced nearly all of its major advances in qualitative nuclear development, for example, the first explosive test of a nuclear device, the first test flight of a missile equipped with a nuclear warhead, the first explosive test of a thermonuclear device and the first test flight of an intercontinental ballistic missile (ICBM). The declarations have provided updates of available information about the quality of its nuclear weapons. China has also exhibited its nuclear delivery systems in parades, for example, on the 35th and 50th anniversaries of the People's Republic of China, thus demonstrating its declared capabilities. Qualitative transparency enables the outside world to assess Chinese nuclear weapons and helps to avoid miscalculations in this regard.

China has never declared the number of its nuclear weapons, the amount of its stockpiled fissile materials or the production rate of new nuclear warheads. When other states make estimates pertaining to China, China neither confirms nor denies these figures. China will most probably maintain a policy of quantitative ambiguity as a way of protecting its nuclear deterrence until it has built a survivable nuclear retaliatory force that relies on geographical ambiguity.

China is ambivalent about clarifying its nuclear activities. On the one hand, if it provides information on nuclear weapon-related activities, such as missile test flights, this could contribute to avoiding suspicion and false alerts in other states. On the other hand, China is concerned that the declaration of such activities would reveal sensitive information to the military intelligence agencies of other states. During the 2000 Review Conference of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), China initially opposed the commitment to increased transparency in nuclear weapon capabilities by the NWS as a voluntary confidence-building measure. It wanted to link transparency to a nuclear no-first-use commitment and to make it dependent on negotiated arms limitation agreements.[6] Based on these considerations, China will clarify the nature of most of its nuclear weapon-related activities after they have taken place. Objections could be raised that some activities could be misinterpreted if advance information about them is not provided, as in the case of missile test flights. Here, China tries to minimize the negative

[5] Dong, J. and Wu, X.: 'True story: China's mysterious strategic missile forces on rise', *Guangzhou Ribao* (Internet edn), 1 July 2001, in 'PRC strategic missile forces mature into "strong shield"', Foreign Broadcast Information Service, *Daily Report–China Program Product* (FBIS-CPP), FBIS-CPP-000-044, 3 July 2001.

[6] See, e.g., Simpson, J., 'The 2000 NPT Review Conference', *SIPRI Yearbook 2001: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2001), p. 495.

effects by taking other approaches. It does not maintain its nuclear weapons on high alert and signed de-targeting agreements with Russia in 1994 and with the USA in 1998.[7] China is an active participant in crisis- and suspicion-reduction activities. It maintains hotline links with Russia and the USA in order to be able to clarify misunderstandings and misinterpretations during and after nuclear weapon-related events.

China has two approaches to visits to its nuclear facilities and favours strict rules to regularize such site visits in order to avoid abuse. For example, in the negotiations on the 1996 Comprehensive Nuclear Test-Ban Treaty (CTBT), China and a number of other concerned states insisted on the need for a large majority of votes to trigger on-site inspections.[8] However, in practice, China is generous about hosting site visits on a voluntary basis. As revealed in 2001, scientists from US nuclear weapon laboratories have 'recorded detailed histories of the Chinese program from top scientists, inspected nuclear weapons labs and bomb testing sites, interviewed Chinese weapons designers, [and] photographed nuclear facilities' in the past 10 or more years.[9] The US scientists even witnessed preparations for a Chinese underground nuclear test.[10] In addition, the Chinese nuclear complex hosts arms control conferences, which have included site visits by foreign civilian experts. For example, during the International School on Disarmament and Research on Conflicts–Beijing Seminar on Arms Control in 1996, the participants of the conference were taken on a tour of 'Science City' in Mianyang, which is a part of a Chinese defence research institute, the China Academy of Engineering Physics. The acceptance of site visits by foreign experts promotes transparency in Chinese nuclear development.

III. Reasons for transparency

There are various reasons for providing transparency in nuclear weapons. The first is to reduce suspicions, the most serious of which are overestimations of nuclear capabilities, misinterpretation of state activities and uncertainties regarding the future of states' nuclear forces. All such suspicions have been a concern for China. If the nuclear capability of China is overestimated by other states, the perceptions of China as a threat would be exacerbated, which in turn could disrupt China's economic relations and economic development.

[7] United Nations, 'Implementation of the comprehensive nuclear-test-ban treaty: general and complete disarmament', URL <http://www.un.org/documents/ga/docs/51/plenary/a51-127.htm>; and 'Joint Statement on South Asia', The White House, Office of the Press Secretary, Washington, DC, 27 June 1998, in 'US–China summit', *Disarmament Diplomacy*, no. 27 (June 1998), available on the Acronym Institute Internet site at URL <http://www.acronym.org.uk/dd/dd27/27china.htm>.

[8] Johnson, R., *A Comprehensive Test Ban Treaty: Signed But Not Sealed*, Acronym Report no. 10, May 1997, available on the Acronym Institute Internet site at URL <http://www.acronym.org.uk/acrorep/acro10.htm>. The compromise that was reached is presented in paragraph 46 and calls for at least 30 affirmative votes by members of the Executive Council for a decision to approve on-site inspections.

[9] Coll, S., 'The man inside China's bomb labs, US blocks memoir of scientist who gathered trove of information', *Washington Post*, 16 May 2001, p. 1.

[10] Coll (note 9).

There are two kinds of nuclear activity in China which could be misinterpreted by other states. A treaty-compliant activity could be suspected of being a violation, which could damage China's international reputation. In addition, a routine or civilian activity in China could be wrongly regarded by other states as a hostile military action, which could trigger aggressive reactions. Because China maintains its nuclear forces at a very low state of alert, the latter kind of misinterpretation is rarely made. The uncertainties in predicting the future of Chinese nuclear forces have been used in some quarters as arguments to criticize China. For example, some advocates of the US National Missile Defense (NMD) programme argue that the USA should disregard China's reactions to NMD development and deployment because China will modernize its nuclear force in any case.[11] This argument uses the uncertainties to minimize the effect that a US NMD deployment could have on Chinese nuclear development.[12]

The second reason for nuclear transparency is to reduce concerns over nuclear proliferation. On many occasions, China has been accused of transferring sensitive nuclear technologies and components to other states. This has put a burden on its diplomatic resources. China now pursues a much more transparent policy by submitting all bilateral nuclear cooperation with other states to International Atomic Energy Agency (IAEA) safeguards. Transparency in this area should help reduce suspicions about Chinese nuclear transfers.

The need to make nuclear deterrence credible constitutes a third reason for nuclear transparency. The nuclear deterrence of a state relies on the adversary's perception of the state's nuclear retaliatory capability. It is therefore important for China to be able to prove its nuclear capability by demonstrating that it can explode nuclear devices, by having the means to deliver them to a certain range and by showing that its nuclear weapons could survive a first strike. If an NMD system is finally deployed by the USA, China will also need to demonstrate that its nuclear weapons can penetrate such defences.

Finally, the fourth reason for nuclear transparency is to promote arms control. Chinese experts have suggested that the excess fissile materials which have resulted from the dismantling and reduction of Russian and US warheads should be subject to international monitoring to prevent Russia and the USA from reversing the reductions.[13] In turn, China may be asked to provide evidence that it is not producing new fissile materials at the same time as Russia and the USA are reducing their nuclear arsenals to a very low level. Such exchanges are integral to compromises in global arms control negotiations.

[11] Perlez, J., 'China likely to modernize nuclear arms, US believes', *New York Times*, 12 May 2000.

[12] The changes in Chinese nuclear development which might be made as a result of NMD deployment are discussed in Li, B., 'The effects of NMD on the Chinese strategy', *Jane's Intelligence Review*, vol. 13, no. 3 (Mar. 2001), pp. 49–52.

[13] Chen, X. and Tian, D., 'The key is to verify and control nuclear explosive materials', *Arms Control Collected Works* (Program for Science and National Security Studies, Institute of Applied Physics and Computational Mathematics: Beijing, 1995), pp. 53–56.

IV. Concerns over transparency

There are two major concerns regarding nuclear transparency. First, certain facets of nuclear transparency may facilitate hostile intelligence activities aimed at identifying the weakness of a nuclear weapon system, thereby helping to exploit such weaknesses through the design of countermeasures. This is a genuine concern for all the NWS. For example, the survivability of a mobile nuclear weapon system, a land-based ICBM or a submarine-launched ballistic missile (SLBM) relies on the geographical ambiguity of the system. If the manoeuvring strategy of the system is known, a potential attacker could increase the kill probability by narrowing the targeting area. China has not acquired operational long-range mobile nuclear weapons; the survivability of its current ICBM force therefore relies on ambiguity surrounding numbers. Because China will not confirm or deny reports on the number of its ICBMs, other states cannot have confidence in any estimates. An attacker considering launching a first strike against China would be uncertain of China's retaliatory capacity. This is how China's nuclear deterrent works today.[14]

Second, some transparency measures could result in the leakage of information about nuclear weapon designs, which may, in turn, lead to nuclear proliferation. The nuclear facilities in all the NWS are regarded as highly sensitive and their nuclear weapon complexes are strictly protected from intrusion. Approaches to protecting sensitive nuclear weapon technologies are always in opposition to approaches to nuclear transparency. If there is no way to find a compatible solution, transparency is sacrificed because nuclear proliferation is regarded as a serious threat by all the NWS. China shares this concern and has developed a system of regulations to protect sensitive information as well as the hardware to prevent illegal access to its facilities.[15]

V. Changing factors in the shaping of China's transparency policy

Some of the factors that shape China's policy on nuclear transparency are changing. First, China is acquiring more survivable nuclear weapons. When China has deployed a mobile nuclear force, it will be much less concerned about the problem of survivability and will be able to rely for its retaliatory capacity on geographical ambiguity instead of quantitative ambiguity. This would constitute a major change in the nature of Chinese nuclear deterrence and give China some leeway to allow greater quantitative nuclear transparency.

[14] For a more detailed discussion of the quantitative ambiguity of the Chinese nuclear arsenal see Li, B., 'China's nuclear disarmament policy', ed. H. A. Feiveson, *The Nuclear Turning Point:* A *Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons* (Brookings Institution Press: Washington, DC, 1999), pp. 325–32.

[15] Yu, J., ['A brief introduction to the National Bureau of Nuclear Safety'], *Fushe Fanghu Tongxun*, vol. 15, no. 2 (1995), pp. 59–62 (in Chinese).

Second, China is involved in the process of globalization, which requires greater transparency in the commercial area. This challenge extends to the nuclear area, where the transformation of routines associated with the old system of secrecy is accelerating. For example, most Chinese defence-related institutes have used post office box numbers as addresses for the sake of secrecy. However, over the past two decades they have begun to provide street addresses to the public and replace the ordinal numbers which previously stood for their departments and institutes with names denoting the activities of these units.

Some defence institutes are increasing their transparency in the process of conversion to civilian purposes. For example, the China Academy of Launch Technology (CALT) is a company engaged in missile production and civilian space-launch services. In order to join the global information network, CALT provides detailed technical parameters of its launch vehicles on its Internet site.[16] This helps those outside China to understand the technical characteristics of some of its missile products. A number of Chinese defence institutes are also using the Internet to describe their work.[17] In addition, China can be expected to introduce many new transparency arrangements after it has joined the World Trade Organization.

Third, new technologies promote increased transparency. The Internet provides a quick and easy way of sharing information. It could also enhance nuclear transparency and help build trust. The Chinese–US laboratory-to-laboratory cooperation project, for example, demonstrated a technology for remote monitoring of fissile materials via the Internet.[18] Unfortunately, this joint project was terminated in the wake of the Cox Report.[19] It would otherwise have enhanced mutual trust in the physical protection of materials and thereby have contributed to non-proliferation efforts.

Another significant factor is commercial satellite imagery, which now has very high resolution and can provide almost global coverage. Past approaches, such as not showing some sensitive areas on maps, are no longer meaningful.

[16] Information on the activities of the China Academy of Launch Technology is available (in Chinese) at URL <http://www.calt.com>.

[17] The brief introduction on the Internet site of the China Academy of Engineering Physics states: 'The China Academy of Engineering Physics, founded in 1958, an independent account in the national planning, is a complex of theoretical, experimental, designing, and production work for developing advanced defence science and technology' (author's translation), URL <http://www.caep.ac.cn> (in Chinese). The China Academy of Engineering Physics presents a map of its 'science city' at URL <http://www.caep.ac.cn/jj/weizhi.htm> (in Chinese).

[18] Prindle, N., 'The US–China lab-to-lab technical exchange program', *Nonproliferation Review*, vol. 5, no. 3 (spring–summer 1998), pp. 111–18, available at URL <http://cns.miis.edu/pubs/npr/vol05/53/prindl53.pdf>.

[19] US Congress, House of Representatives, Select Committee on US National Security and Military/Commercial Concerns with the People's Republic of China, *Final Report,* House Report 105-851 (US Government Printing Office: Washington, DC, 25 May 1999), URL <http://www.gpo.gov/congress/house/hr105851>; and May, M. (ed.), *The Cox Committee Report: An Assessment* (Center for International Security and Cooperation: Stanford, Calif., 1999), available at URL <http://ldml.stanford.edu/cisac/pdf/cox.pdf>.

VI. Conclusions

China's approach to nuclear transparency is based primarily on security considerations, including the maintenance of effective nuclear deterrence and the reduction of suspicions by other states regarding Chinese nuclear forces and activities. China is currently increasing the survivability of its nuclear weapons and continuing its efforts to implement reform and openness. These factors will increase its confidence that transparency in nuclear weapons is the right policy.

4. Transparency and security in Russian–US nuclear relations

Alexander Pikayev

I. A historical overview

In the late 1940s, at the start of the cold war, the only means available to the Soviet Union and the United States for obtaining information about the other side's nuclear developments was intelligence activity. Throughout the 1950s the USSR used primarily human intelligence, while the USA increasingly used technical reconnaissance means, including U-2 high-altitude reconnaissance flights over Soviet territory and ground- and sea-based electronic surveillance. In retrospect, it is clear that the information acquired by these means provided an incomplete picture of both Soviet and US nuclear developments, which resulted in faulty perceptions and overestimations of the other side's nuclear capabilities. Most strikingly, US overestimations of Soviet bomber forces in the 1950s and of Soviet missile forces in the 1960s led to an expensive and unnecessary build-up of US capabilities.

By the early 1960s the USA and the USSR had developed important new technical tools for transparency[1]—satellites orbiting the earth. Along with the availability of technologies for remote monitoring, satellites enabled the two states to obtain much broader and more consistent information. Satellites became and still are the most important technical means for verifying the Soviet/Russian–US nuclear arms control agreements concluded from the 1970s to the 1990s.[2]

In the 1970s and 1980s, the USA and the USSR developed a more cooperative nuclear relationship. They negotiated several arms control agreements, the most important of which are the 1972 SALT I Interim Agreement, the 1979 Treaty on the Limitation of Strategic Offensive Arms (SALT II) and the 1972 Treaty on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty). These treaties imposed limits on further Soviet and US strategic nuclear build-ups and marked a significant change in both countries' attitudes towards transparency, since there was a need to verify compliance with them. While in the 1950s and 1960s obtaining information about another state's arsenal was regarded as espionage, in the early 1970s both countries realized that a certain level of transparency was necessary for verification purposes and that the ensu-

[1] In this chapter 'verification' refers to the monitoring of compliance with treaties and agreements. 'Transparency' is used in a broad sense, referring to information as well as to its accessibility and reliability.

[2] For a detailed analysis of verification measures see part II of this volume.

ing vulnerability was mutual. In negotiating the SALT and ABM treaties, the USA and the USSR tacitly agreed that compliance would be verified by national technical means (NTM) and that interfering with such activities was prohibited.

In addition to remote monitoring, the USA and the USSR began to use other verification and transparency measures—data exchanges and prior notifications. Data exchanges on the number of strategic nuclear delivery vehicles (SNDVs) took place in the context of the SALT negotiations, and prior notification of some missile launches and tests was required by a Soviet–US agreement.[3] These notifications were in essence transparency measures aimed at building confidence and reducing the risk of an accidental outbreak of nuclear war.

In the 1950s and 1960s, the USSR was not interested in transparency, in part because it was believed that it would reveal the Soviet nuclear inferiority vis-à-vis the USA. The more cooperative approach of the 1970s and 1980s became possible only after the USSR had reached strategic nuclear parity—an approximately equal level of deployed strategic nuclear forces—with the USA.[4] The effective end of asymmetry deprived the USA of the ability to launch a disarming first strike against the USSR. Consequently, the USSR's interest in maintaining a robust deterrent, *inter alia* through non-transparency, decreased. More importantly, with the ABM Treaty, the relative mutual vulnerability of comparable arsenals became a cornerstone of Soviet–US strategic stability. This vulnerability reduced both sides' motivation to launch a first strike because the potential damage from a retaliatory strike would have exceeded the advantage of an attack.

In the late 1980s—with the advent of Soviet President Mikhail Gorbachev's *perestroika* and *novoe myshlenie*—bilateral nuclear disarmament became a centrepiece of the efforts to overcome the mistrust of the cold war period. The new political environment opened the door for the unprecedented 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty), which called for the complete elimination of an entire class of Soviet and US land-based ballistic and cruise missiles, those with a range of 500–5500 kilometres.[5]

The INF Treaty established an intrusive verification regime that went beyond the use of traditional NTM.[6] The major innovation was the acceptance of on-site inspections (OSIs). Soviet and US inspectors were allowed to monitor the com-

[3] The US–Soviet Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War was signed on 30 Sep. 1971 and entered into force the same day. The USA and the USSR agreed to notify each other in certain situations presenting a risk of nuclear war, including accidental or unauthorized launch of a nuclear weapon and the detection of unidentified objects by missile warning systems. The 2 nations pledged to notify each other of planned missile launches beyond the national territory. United Nations, *Treaty Series,* vol. 807 (UN: New York, 1972).

[4] Strictly speaking, quantitative parity in strategic nuclear force levels was reached in the late 1970s. However, the levels of the Soviet forces had become comparable to those of the USA by the late 1960s.

[5] For an account of the negotiations and the text of the INF Treaty see Dean, J., 'The INF Treaty negotiations', *SIPRI Yearbook 1988: World Armaments and Disarmament* (Oxford University Press: Oxford, 1988), pp. 375–489.

[6] The INF Treaty was fully implemented by the 2 parties before the deadline of 1 June 1991 and its inspection regime was discontinued on 31 May 2001.

plete life cycle of intermediate-range missiles—from the production facilities, bases and storage areas to the elimination sites. The INF Treaty provided for several types of inspection to facilitate verification, including continuous (or portal) monitoring and short-notice challenge inspections. This meant that remote monitoring by NTM was supplemented by monitoring at the perimeter of, or even inside, certain nuclear weapon facilities.

The verification procedures of the INF Treaty paved the way for negotiations on the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty). Under START I, the USA and the USSR undertook, for the first time, to reduce their arsenals of deployed strategic nuclear weapons rather than limit their growth.[7] Like the INF Treaty, the START I Treaty emphasizes cooperative verification measures, including various types of OSI. It also requires detailed exchanges of data every six months on SNDVs, including their performance, bases, production and dismantlement facilities, and status.

Several conclusions can be drawn from reviewing the history of transparency in Soviet–US nuclear relations from the 1950s to the early 1990s.

1. During this period, bilateral transparency in nuclear assets gradually increased and became more intrusive.
2. It was possible to negotiate cooperative transparency measures only after there was near-parity in the strategic nuclear arsenals of the two powers and when fears of a disarming first strike were alleviated.
3. The more substantial the strategic nuclear limitations and reductions agreed, the more intrusive and far-reaching was the transparency which accompanied them.
4. Positive developments in general bilateral political relations were essential preconditions for the breakthroughs in transparency of the late 1980s.

II. Post-cold war developments

The period immediately following the collapse of the USSR and the end of the cold war marked a further expansion of Russian–US cooperation in the nuclear field, including transparency measures. Despite the achievements of the late 1980s and early 1990s, the bilateral strategic arms control regime regulated only a segment of the nuclear arsenals of both powers. Strictly speaking, it imposed limits on strategic SNDVs and led only to the elimination of intermediate-range land-based missiles. While these restrictions indirectly affected the deployment and the number of nuclear warheads associated with those delivery vehicles, none of the agreements negotiated by the time of the Soviet collapse imposed specific limits on warheads—nor was any meaningful

[7] The reductions under the START I Treaty were successfully completed by 5 Dec. 2001. US Department of State, Bureau of Arms Control, 'Fact Sheet: START Treaty final reductions', 5 Dec. 2001, URL <http://www.state.gov/t/ac/rls/fs/2001/6669.htm>.

transparency scheme introduced for warheads or for weapon-grade fissile materials.

On 27 September and 6 October 1991, presidents George H. W. Bush and Mikhail Gorbachev, respectively, announced their intentions to carry out reciprocal, parallel withdrawals of tactical nuclear warheads from military units to storage sites. In January 1992 Russian President Boris Yeltsin further expanded the Gorbachev initiatives. Although the primary driving force behind the 1991–92 Bush–Gorbachev/Yeltsin initiatives, known as the Presidential Nuclear Initiatives (PNIs), was concern about the consolidation of the tactical nuclear arsenal of the increasingly unstable USSR into secure storage in Russia, they also helped to address the gap in nuclear disarmament left by negotiated strategic arms control.[8]

Under the Bush initiative, the USA decided to withdraw to its territory a major portion of its tactical nuclear weapons located abroad, including artillery shells, short-range missiles, gravity bombs and nuclear weapons aboard US surface naval vessels. An unspecified number of US gravity bombs remain stored in US military bases in Europe.[9]

In response, the USSR and later Russia agreed on a set of measures that were expected to be implemented by the end of 2000. These included: (*a*) the withdrawal of all nuclear weapons from the former USSR to Russian territory; (*b*) the withdrawal of all non-strategic nuclear warheads from naval vessels; (*c)* the complete elimination of warheads designated for tactical land-based missiles, artillery shells and landmines; (*d*) the partial elimination of warheads for naval aviation; (*e*) the elimination of half the number of warheads for tactical aircraft; (*f*) the elimination of one-third of the number of warheads removed from naval vessels; (*g*) the elimination of half the number of warheads designated for air defence missiles; and (*h*) the storage in central sites of two-thirds of the warheads removed from naval vessels, half of the warheads removed from anti-ballistic and anti-aircraft missiles, and all non-eliminated warheads removed from naval aviation.

When these measures are fully implemented, only half of the warheads designated for tactical aircraft will remain on military bases. All other warheads would be either eliminated or moved to central storage sites. However, these measures did not have to be verified by data exchanges or transparency measures, which makes the status of their implementation a subject of speculation. What is known is that, according to official statements, the withdrawal of former Soviet tactical nuclear warheads to Russian territory was completed by May 1992 and that of strategic warheads by November 1996. In April 2000, at the Review Conference for the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), Russian Minister of Foreign Affairs

[8] Fieldhouse, R., 'Nuclear weapon developments and unilateral reduction initiatives', *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), pp. 67–84; excerpts from the PNIs are reproduced in appendix 2A, pp. 85–92.

[9] See, e.g., Zarimpas, N., 'Tactical nuclear weapons', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 571–75.

Igor Ivanov stated that by that time Moscow had eliminated one-third of the warheads removed from naval vessels and half of the warheads removed from air defence missiles and gravity bombs, and was close to having completely eliminated all warheads from tactical land-based missiles, artillery shells and landmines.[10] In April 2002 Russia stated that the full implementation of the PNIs would be delayed until 2004 for financial reasons.[11]

Transparency in nuclear materials and warhead production

The collapse of the USSR focused international attention on the problem of the redundancy of its arsenals of nuclear warheads and materials and the danger that they could be diverted to unauthorized use. In the early 1990s the international media published numerous reports claiming that Russian nuclear assets had been diverted. Some of the cases involving nuclear material were later confirmed by Russia. In 1991, in order to pre-empt such diversion, the US Congress adopted a law which provided for the Cooperative Threat Reduction (CTR) programme, also called the Nunn–Lugar programme after the two senators who co-sponsored the original authorizing legislation. In December 1991 President Bush signed it into law. The CTR programme has three goals: (*a*) to assist the former Soviet states in destroying its non-conventional weapons, that is, nuclear, biological and chemical weapons and other sophisticated arms; (*b*) to assist in safely transporting, storing, disabling and safeguarding such weapons; and (*c*) to establish effective mechanisms against the proliferation of these weapons.[12]

Under the CTR programme, another set of bilateral initiatives was adopted and partially implemented in the 1990s. They attempted to introduce transparency in excess weapon-grade fissile materials, fresh and spent nuclear fuel for various nuclear-related systems, and, to some extent, in warhead dismantlement. Transparency was strengthened within the framework of numerous Russian–US efforts to reduce the risk of the proliferation of nuclear materials from Russia and other former Soviet states. Moreover, these measures were intended to facilitate Russia's fulfilment of obligations under formal strategic arms control agreements and the 1991–92 PNIs.[13]

In contrast to transparency measures negotiated during the cold war, the transparency programme set up by these initiatives is asymmetrical, giving

[10] Ivanov, I. S., 'Statement at the Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, New York, 25 Apr. 2000', available at the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/resources/npt2000ivanov.htm>.

[11] 'Statement of the Delegation of the Russian Federation at the First Session of the Preparatory Committee for the 2005 NPT Review Conference under Article VI of the Treaty, New York, 11 Apr. 2002', URL <http://www.ln.mid.ru/bl.nsf/arh/F8906FA2A4723ef843256ba300394EAE>.

[12] Wolfsthal, J. B., Chuen, C.-A. and Daughtry, E. E. (eds), *Nuclear Status Report: Nuclear Weapons, Fissile Materials, and Export Controls in the Former Soviet Union*, no. 6 (Carnegie Endowment for International Peace: Washington, DC, and Monterey Institute of International Studies: Monterey, Calif., June 2001), p. 47, available at URL <http://ceip.org/files/pdf/Status.pdf>.

[13] Zarimpas (note 9).

more rights to the USA since the US Government finances these projects and makes the provision of funds conditional on obtaining access to the facilities that receive assistance. The basic idea is that the USA provides funding for consolidating and enhancing the custodial security of Russian nuclear materials in exchange for greater openness in the Russian nuclear complex.

The 1993 Russian–US Highly Enriched Uranium (HEU) Agreement, which has an important transparency dimension, might be considered the most significant achievement among such efforts.[14] Under the agreement, HEU from dismantled Russian warheads is down-blended in Russia and then delivered to the USA where, after further processing, it is used as fuel for US nuclear power plants. The overall gain for Russia was initially estimated at $12 billion but in reality it will be less than this.[15]

According to the HEU Agreement, Russia must dismantle several thousand strategic and tactical nuclear warheads. Consequently, through the transparency provisions, the USA has gained an opportunity to indirectly obtain more information on the disassembly of Russia's nuclear warheads. Although actual warhead disassembly is not monitored, US teams of experts have gained a better understanding of the processes and materials involved. The transparency measures include both US visits to and monitoring of Russian facilities where the HEU is down-blended, in order to verify that the HEU is actually extracted from dismantled warheads. However, no measures have been agreed for enabling inspectors to verify the weapon origin of the material. In a reciprocal provision, Russia is allowed to conduct monitoring at US plants in order to verify that low enriched uranium shipped from Russia is not re-enriched in the USA for weapon manufacture.

Another major bilateral programme that is being successfully implemented is aimed at improving material protection, control and accounting (MPC&A) of Russian nuclear materials. This programme is funded under the auspices of the US Department of Energy and provides the USA with an opportunity to make regular visits to almost all the Russian facilities where nuclear materials, including weapon-grade material, are located. Within the MPC&A programme, similar arrangements were negotiated in the late 1990s for several Russian Navy facilities where both fresh and spent fuel for nuclear-powered naval vessels is kept. However, Russia refused to grant the USA access to four key warhead assembly and dismantlement plants, located in the four 'closed' cities of Lesnoy, Sarov, Trekhgorny and Zarechny. As a result, the USA refused to provide MPC&A assistance to those facilities. A similar deadlock over assistance to research and development facilities in Sarov and Snezhinsk may eventually be broken as a result of intensive talks on access.

[14] The text of the HEU Agreement is reproduced in *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), pp. 673–75.

[15] The HEU Agreement was later renegotiated, making the amount to be paid to Russia dependent on market forces. Given the fall in uranium prices after the deal was concluded, the revision suggested that Russia's overall income would be less than expected. Neff, T., 'Privatizing US national security: the US–Russian HEU deal at risk', *Arms Control Today*, vol. 28, no. 6 (Aug./Sep. 1998), pp. 8–14.

In two other important initiatives, progress is slow because of disagreements over transparency. The first is the construction of a fissile materials storage facility at Mayak (in the Ural Mountains) for the purpose of storing components extracted from dismantled nuclear weapons, including plutonium pits. The USA made its assistance conditional on Russia's acceptance of intrusive transparency measures. Although Russia has accepted US visits and random inspections at the Mayak facility, it has declined the US proposals aimed at verifying the origin of the material. Reportedly, the proposals included transparency measures to be implemented outside the future storage site, including the establishment of an 'upstream' chain of custody, specifically involving the plutonium pit conversion plant at Mayak.

The second important agreement is the 1996 Trilateral Initiative between Russia, the USA and the International Atomic Energy Agency (IAEA). The Trilateral Initiative was officially launched in September 1996 and was aimed at negotiating transparency measures to ensure that the excess weapon-grade fissile materials of both countries would not be reused in the production of nuclear weapons. Verification is to be implemented by the IAEA. Originally, Russia participated in the initiative in order to resolve its disagreements with the USA over the verification of arrangements at the Mayak storage facility. Although the three sides continuously report 'constant progress' in the talks, the absence of an agreement after more than five years of discussions demonstrates that progress is slow. Disagreements on how to find a balance between verification requirements and the protection of classified data remain unresolved.[16]

The last promising development in the area of transparency took place in the spring of 2001, when Russia and Belarus ratified the 1992 Treaty on Open Skies, which obligates the parties to submit their territories to short-notice unarmed surveillance flights.[17] The area of application stretches from Vancouver, Canada, eastward to Vladivostok, Russia. The Open Skies Treaty entered into force on 1 January 2002. Indirectly, it might represent a useful multilateral mechanism for greater transparency in nuclear assets in Russia and the USA. For instance, the overflights might become an additional remote monitoring measure to track changes in the deployment of nuclear warheads.

Non-traditional bilateral initiatives adopted in the 1990s helped to expand bilateral transparency measures to nuclear warheads and materials. Although no transparency measures have been applied to nuclear warheads, certain measures were agreed regarding fissile materials. The measures were incomplete and fragmented, but they permitted the establishment of a set of transparency regimes parallel to those based on formal strategic arms control agreements. Success in the implementation of these initiatives depended directly on the extent of the funding that the USA was ready to provide for a specific project and on the level of sensitivity of the facilities involved: the more funds and the

[16] See also chapters 5, 10 and 11 in this volume.

[17] 'All conditions fulfilled for Open Skies Treaty to enter into force', Press Release, Organization for Security and Co-operation in Europe (OSCE) Secretariat, Vienna, 5 Nov. 2001. The text of the treaty is available on the OSCE Internet site at URL <http://www.osce.org/docs/english/oskiese.htm>.

less sensitivity, the more successful the implementation. Russia often complained that the agreed measures were asymmetrical, leaving the US assets relatively less transparent. The USA countered that its programmes were in general more open and that there was not much for Russia to learn that was not already known. The initiatives covered only small segments of Russia's nuclear complex and thus failed to motivate Russia or the USA to disclose data on their stockpiles of nuclear weapons and weapon-grade fissile materials. A decade after the end of the cold war, the bulk of the nuclear holdings of Russia and the USA remain non-transparent.

Russian–US interest in nuclear warhead transparency and dismantlement

The 'transparency through assistance' efforts failed to address the issue of nuclear warhead transparency. From the very beginning Russia rejected the US attempts to gain access to its warhead facilities in exchange for assistance with warhead dismantlement or with improving the safety of nuclear materials. As soon as the most sensitive facilities appeared on the list of those to receive assistance, Russia refused to grant the USA the access it sought. As a result, the USA did not provide assistance for warhead dismantlement per se but did assist in such important but marginal activities as safe warhead transportation. It also facilitated and promoted dismantlement through the HEU and storage facility projects.

The 1997 Joint Statement

In 1997 Russia and the USA made their most recent attempt to include nuclear warheads in a formal bilateral nuclear control regime. On 21 March, at their Helsinki summit meeting, presidents Bill Clinton and Boris Yeltsin signed the Joint Statement on Parameters on Future Reductions in Nuclear Forces,[18] which opened the door for the discussion of transparency in warheads under three provisions.

First, the Joint Statement stipulated that a future START III accord should contain measures aimed at making available data on the numbers and yields of strategic nuclear warheads, as well as data on their elimination. The accord was also to guarantee that deep reductions in warheads would be irreversible. To implement these deep reductions, technical and organizational measures should be agreed. This provision required not only that there should be an exchange of data on numbers, capabilities and the elimination of strategic nuclear warheads but also that this exchange should be verified. If a START III agreement had been concluded, it might have included storage sites for strategic nuclear warheads and, perhaps, their production and elimination facilities and transporta-

[18] Joint Statement on Parameters on Future Reductions in Nuclear Forces, The White House, Office of the Press Secretary, Washington, DC, 21 Mar. 1997, available on the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/resources/summits6.htm#parameters>.

tion, in a transparency regime. However, the text of the Joint Statement permitted the interpretation that the irreversibility of the strategic warheads reductions could be achieved either by warhead elimination or by other technical and organizational measures, which were not specified and had not been negotiated.

Second, the Joint Statement called for the discussion of possible measures related to long-range sea-launched cruise missiles (SLCMs) and tactical nuclear systems. Expert discussions were to take place in the context of, but separately from, the START III negotiations. Again, this provision is open to two interpretations. According to one, 'tactical nuclear systems' refers to carriers only, not warheads. According to the other interpretation, the nuclear warheads attributed to the missiles are included, marking the Joint Statement as the first Russian–US document that could have triggered a dialogue on tactical nuclear warheads at the expert level. In addition, the provision required the negotiation of appropriate confidence-building and transparency measures with regard to SLCMs and tactical nuclear systems. Consequently, it might have improved the prospects for transparency in part of the stockpiles of tactical nuclear warheads or their delivery vehicles.

Third, the Joint Statement contained a provision that the parties would deactivate the delivery vehicles scheduled for elimination by 31 December 2003, the original deadline for the implementation of the 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms (START II Treaty).[19] This early deactivation was to be carried out either by removing the warheads from their delivery vehicles or by 'taking other jointly agreed steps', which had not been determined. Finally, the USA stated that it would provide assistance, via the CTR programme, to facilitate early deactivation.

This 'early deactivation' provision was not incorporated into the START II Protocol, signed by Russia and the USA on 26 September 1997.[20] Instead, it was codified by an exchange of letters between Russian Minister of Foreign Affairs Yevgeniy Primakov and US Secretary of State Madeleine Albright. The two sides proposed to start expert consultations on early deactivation immediately after the START II Treaty entered into force. In both letters, the consultations were directly linked to US assistance. In Primakov's letter it was also stated that agreements made by Russia were based on the assumption that a START III accord would enter into force before early deactivation was completed, that is, by 31 December 2003.[21] Therefore, all three provisions of the Joint Statement related to nuclear warhead transparency were directly linked to a START III accord.

[19] For a description of the provisions of the START II Treaty see Lockwood, D., 'Nuclear arms control', *SIPRI Yearbook 1993: World Armaments and Disarmament* (Oxford University Press: Oxford, 1993), pp. 554–59. The treaty never entered into force; on 14 June 2002, as a response to the expiration of the ABM Treaty on 13 June, Russia declared that it will no longer be bound by the START II Treaty.

[20] See, e.g., Arms Control Association, 'Fact Sheet: START II and its extension protocol at a glance', (n.d.), URL <http://www.armscontrol.org/factsheets/start2.asp>.

[21] 'Fact Sheet on START II Protocol, letters on early deactivation', *Washington File* (United States Information Service, US Embassy: Stockholm, 26 Sep. 1997).

In summary, the Joint Statement opened prospects for the negotiation of a legal regime of transparency in strategic nuclear warheads through the START III talks on early deactivation of Russian MIRVed (equipped with multiple independently targetable re-entry vehicles) missiles. In parallel, through expert discussions, another agreement was reached to expand the transparency regime to cover tactical warheads attributed to tactical missiles and long-range SLCMs. In other words, at least a back door was opened for the negotiation of formal bilateral arms control regimes with associated transparency measures covering all tactical nuclear warheads, which remained open after the implementation of the PNIs.

The March 1997 Joint Statement contained a strict linkage between the commencement of START III negotiations and the ratification of the START II Treaty by Russia (the US Senate ratified the treaty on 26 January 1996). Because of domestic political debates and Russian–US disagreements over the air raids against Iraq in the winter of 1998/99 and the NATO bombing campaign in Yugoslavia in March–June 1999, Russia did not approve ratification until April 2000—three years after the Helsinki summit meeting. However, Article 9 of the Russian Law on Ratification contained a stipulation that Russia would not exchange the instruments of ratification until the US Senate had approved the set of ABM Treaty-related agreements that were signed at the same time as the START II Protocol.[22]

This provision effectively blocked entry into force of the START II Treaty since these agreements faced strong opposition in the US Senate. The Republicans believed that the collapse of the USSR had rendered the ABM Treaty null and void and that approval of the 1997 agreements might be interpreted as an admission to the contrary. As a result, the Clinton Administration decided not to submit either these agreements or the START II Protocol to the Senate since there was little chance that the Senate would approve the ABM Treaty-related agreements.

In summary, the complicated balance of compromises reached at Helsinki and codified at New York did not survive. Despite the surprising Russian ratification, the START II Treaty did not enter into force, and the framework for a follow-on START III accord set out in the Joint Statement collapsed. It became clear that there was little prospect of moving ahead with deeper reductions in nuclear arms without first cutting the START II–ABM Treaty-related Gordian knot, which has been tied by the legislatures in both Russia and the USA.

[22] The set of agreements was signed in New York on 26 Sep. 1997 by Belarus, Kazakhstan, Russia, Ukraine and the USA. It consisted of: the Memorandum of Understanding on Succession (MOUS), 2 Agreed Statements, and the Agreement on Confidence-Building Measures related to Systems to Counter Ballistic Missiles other than Strategic Ballistic Missiles. The MOUS recognized Russia, Belarus, Ukraine and Kazakhstan as successor states of the USSR vis-à-vis the ABM Treaty. The Agreed Statements set out technical parameters to clarify the demarcation line between non-strategic missile defences, which were permitted by the ABM Treaty, and strategic missile defences, which were restricted by the treaty. In order to alleviate concerns that tests of non-strategic interceptors might be used to circumvent the treaty, the states parties agreed on a set of confidence-building measures. The agreements would enter into force only after their ratification by the legislatures of the 5 countries. The USA did not ratify them and they became moot with the demise of the ABM Treaty in 2002.

Transparency versus force levels

The end of the cold war and the ensuing changes in the 1990s created an interesting debate in both Russia and the USA with regard to bilateral strategic arms control. On the one hand, considering the long life of nuclear weapons, Russia would be able to maintain approximate numerical strategic nuclear parity with the USA for a few more years. Consequently, the arms control regimes would still maintain their regulatory role in stabilizing the bilateral deterrence relationship. On the other hand, despite all the points of contention, the improved political relations between Russia and the USA, together with growing asymmetries between the two countries, meant that strategic arms control regimes received significantly less priority in their national security policies. In the 1990s, even nuclear arms control efforts gave way to assistance measures under the umbrella of numerous bilateral CTR programmes.

Moreover, Russia's continuing decline caused it to be removed from the centre of US national security calculations. Indeed, it would seem that Russia could not challenge US interests overseas, as it did during the cold war. In fiscal year (FY) 2002 Russia's defence budget was about $9 billion, compared to the US defence budget of over $300 billion.[23] With such huge asymmetry, it would hardly be possible for Russia to maintain approximate nuclear parity with the USA if the USA decided to maintain START I strategic forces levels. According to most estimates, Russia's strategic nuclear deterrent will, for economic reasons, decline from its recent level of about 5500 deployed warheads to the low thousands or even hundreds within the next 10–15 years, irrespective of the fate of arms control regimes.

From a US perspective, if Russia's forces are going to decline dramatically anyway, it would make little sense to enter into complicated and difficult arms control talks with Russia, as they could trigger domestic debates and result in a call for reciprocal concessions. Under the prevailing circumstances the USA has naturally started to lose interest in a substantial part of the formal bilateral negotiated arms control mechanisms—both existing and prospective.

At the same time, the USA maintains an interest in continuing—and even increasing—the transparency in Russia's nuclear arsenals and weapon production complex. This is partly because of concerns that the large nuclear weapon stockpile and know-how in Russia could be diverted to states seeking to acquire nuclear weapons or to non-state terrorist actors that could significantly threaten US policies and interests abroad and even US territory. Transparency, coupled

[23] Romashkin, P. B., Col. (Ret.), Advisor, Yabloko faction, State Duma of the Federal Assembly of the Russian Federation, 'Military expenditures in the federal budget for 2002', Oct. 2001, available on the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/pdf/Romashkin.pdf>. For FY 2002, the Russian Government requested *c.* 280 billion roubles. For 2002, the official average estimate of the rouble/US dollar exchange rate is expected to be 32 : 1. The national defence budget of Russia could therefore slightly exceed $9 billion. For the US figures, see *National Defense Budget Estimates for the Amended FY 2002 Budget* (Green Book), Office of the Under Secretary of Defense (Comptroller), Aug. 2001,URL <http://www.dtic.mil/comptroller/fy2002budget/>.

with safety measures, would help to reduce that risk or at least facilitate the detection of diversion at an early stage.

Another reason for the USA's interest in transparency beyond existing regimes can be found in military planning. It is known that Russia's strategic forces are—and most certainly will remain—below treaty ceilings. However, the scale of and schedule for future Russian reductions are uncertain. This complicates long-term US force planning and was perhaps one of the important reasons for the delays in the completion of the US Nuclear Posture Review in 2001.

For its part, Russia faces an even more complicated dichotomy. One school there believes that arms control regimes—and the transparency inevitably associated with them—represent the only tool available for restricting the military deployments of the superior side. Therefore, maintaining the regimes is in Russia's interest. For this school of thought, the only way to maintain strategic nuclear parity with the USA is to conclude a new strategic nuclear reductions agreement, with overall ceilings below 2000 warheads.

The other school in Russia argues that the weaker side should not invest too much in arms control—especially not in transparency. In their opinion, post-cold war nuclear arms reduction agreements have codified asymmetries in the size and structure of the US and Russian nuclear forces, to the disadvantage of the latter. One of their main criticisms was that the START II Treaty's permissive provisions for 'downloading' launch vehicles had the effect of leaving the USA in a better position than Russia to rapidly reconstitute its strategic forces by redeploying stored nuclear warheads on land- and sea-based ballistic missiles; the USA could gain up to a 6 : 1 advantage over Russia in the number of deployed strategic nuclear warheads. At the same time, START II required the parties to give up MIRVed intercontinental ballistic missiles—the cornerstone of the Russian strategic triad. Taken together, these provisions were seen as having a grossly inequitable impact on Russia's strategic nuclear forces, in effect making the weak even weaker.[24]

If, or when, Russian–US asymmetries in strategic nuclear deployments do become a reality, transparency in deployed arsenals might cause growing national security concerns. Under conditions of asymmetry, it could be argued that transparency is destabilizing. For inferior forces, transparency increases the sense of vulnerability. Since the weaker side perceives that the details of its smaller nuclear capabilities are well known to the stronger side, in time of crisis it might have a stronger motivation to use its weapons first, so as not to risk losing them in a disarming attack. This concern might also lead the weaker state to maintain its forces on high alert status, so as to be able to launch them before they are destroyed.

Generally speaking, a weaker state would want to keep its nuclear capabilities as ambiguous as possible in order to prevent their destruction in a disarming

[24] For more on this debate see, e.g., Pikayev, A., *The Rise and Fall of START II: The Russian View* (Carnegie Endowment for International Peace: Washington, DC, 1999), available at URL <http://www.ceip.org/files/Publications/pikayev.asp>.

attack and in order to have them for deterrence purposes. For this reason, the greater the asymmetries in numbers of deployed nuclear weapons, the stronger will be the pressure to reduce the level of transparency.

A new strategic framework?

Today, it is obvious that Russia and the USA have different priorities in their cooperative nuclear relations. The USA is clearly no longer interested in limiting Russia's nuclear force levels through arms control but still wants to strengthen transparency and ensure predictability. For its part, Russia has become perhaps even more interested than during the cold war in lowering the US force levels through arms control limitations. At the same time, a likely departure from approximate numerical parity in strategic nuclear force levels might increasingly press Russia to reduce transparency in its deployed and stored forces.

This basic imbalance significantly shaped Russian–US debates on a new strategic framework for bilateral relations in 2001 and early 2002. The term 'new strategic framework' was used for the first time by US President George W. Bush in his address to the students and faculty of the National Defense University in Washington, DC on 1 May 2001.[25] Bush declared that Russia and the USA were no longer enemies and that their relations should therefore not be regulated by such legacies of the cold war as the ABM Treaty. Moreover, the Bush Administration expressed its discontent with formal strategic arms control agreements, which it sees as inhibiting US flexibility to respond to new threats in an evolving security environment. While the Bush Administration carefully avoided characterizing the START process as a cold war legacy, it was silent on possible future development of the START agreements. Dissatisfaction with arms control negotiations was reflected in the statement by US Secretary of Defense Donald Rumsfeld to the effect that only enemies have negotiations, while friends hold consultations.[26]

Russia, in contrast, reiterated its commitment to traditional strategic arms control negotiations and legally binding treaties. It has indicated its potential willingness to pursue deep strategic nuclear reductions down to 1000 deployed strategic warheads, not only through measures negotiated with the USA but also through parallel unilateral steps. Russia also firmly retained its conviction that the ABM Treaty had not become irrelevant and still represented a cornerstone not only of bilateral stability but also of global security.[27] In fact, from

[25] 'Remarks by the President to students and faculty at National Defense University', Fort Lesley J. Mcnair, The White House, Office of the Press Secretary, Washington, DC, 1 May 2001, URL <http://www.whitehouse.gov/news/releases/2001/05/20010501-10.html>.

[26] See, e.g., Cirincione, J. and Wolfsthal, J. B., 'What if the new strategic framework goes bad?', *Arms Control Today*, vol. 31, no. 9 (Nov. 2001), p. 6, available at URL <http://www.armscontrol.org/act/2001_11/cirincionenov01.asp#bio>.

[27] See e.g., Letter dated 20 April 2000 from the Permanent Representative of the Russian Federation addressed to the Secretary-General of the Conference transmitting the text of a statement made on 14 April 2000 by Mr. Vladimir V. Putin, Acting President of the Russian Federation, in connection with the ratification by the State Duma of the Federal Assembly of the Russian Federation of the START-II Treaty and

time to time Russia had threatened to abandon a number of important arms control agreements if the USA unilaterally withdrew from the ABM Treaty. The list of treaties which might be affected by Russian reciprocal action included the START I and INF treaties and even the CFE Treaty.

Bush and Putin met for the first time at a summit meeting in Ljubljana, Slovenia, on 16 June 2001. Despite the tension inherent in their positions, they agreed to initiate a 'constructive dialogue' on the improvement of strategic stability.[28] The two presidents met again on 22 July 2001 at a meeting of the Group of Eight industrialized nations in Genoa, where they agreed to begin consultations on strategic offensive and defensive weapons with an understanding that discussions of these two types of armament would be linked.[29]

After the 11 September 2001 terrorist attacks on the USA, Russian–US relations improved. In the course of subsequent Russian–US talks, Russia changed its position against modification of the ABM Treaty. Russian Foreign Minister Igor Ivanov stated that Russia might accept the replacement of the ABM Treaty with a new document that more adequately reflected the new security realities.[30] During the October 2001 meeting between presidents Bush and Putin in Shanghai, hopes that the ABM Treaty controversy would be resolved were further raised. Reportedly, Russia was prepared to amend the treaty in order to permit some testing of US missile defence systems. However, the Bush Administration was unwilling to accept the Russian proposals for amendments to the treaty that would lead to any restrictions on US tests of anti-missile systems.[31] Instead, it sought a mutual withdrawal from the treaty.[32]

At the Russian–US summit meeting held in Washington, DC and Crawford, Texas, in November 2001, the two sides failed to reach agreement on the ABM Treaty. As a result, in late November the Bush Administration decided to withdraw from the treaty unilaterally. On 13 December, in accordance with Article XV of the treaty, the USA gave formal notification that it would withdraw from the ABM Treaty, to take effect six months later. President Putin characterized the US decision as a mistake but avoided undertaking any reciprocal action.[33]

of the package of 1997 agreements on anti-missile defence, Conference on Disarmament document CD/1611, 25 Apr. 2000, available at URL <http://www.unog.ch/disarm/curdoc/1611.htm>.

[28] Tyler, P., 'Bush and Putin: new era of trust?', *International Herald Tribune*, 18 June 2001, pp. 1, 4.

[29] Joint Statement by President Bush and President Putin on Upcoming Consultations on Strategic Issues, The White House, Office of the Press Secretary, Washington, DC, 22 July 2001, URL <http://www.whitehouse.gov/news/releases/2001/07/20010722-6.html>.

[30] 'The Russian Foreign Minister will hand over a personal message from the Russian President to the President of the USA', *Pravda* (Internet edn), 19 Sep. 2001, URL <http://english.pravda.ru/diplomatic/2001/09/19/15581.html>.

[31] Under Article XIV of the ABM Treaty, the parties may amend the document. Amendments would enter into force after ratification. The treaty was amended in the 1974 Protocol, which introduced further numerical restrictions on permitted ballistic missile defences.

[32] Mufson, S. and La Franiere, S., 'ABM Treaty withdrawal: a turning point in arms control', *Washington Post*, 13 Dec. 2001, pp. A1, 13.

[33] 'A statement made by Russian President Vladimir Putin on December 13, 2001, regarding the decision of the administration of the United States of America to withdraw from the Anti-Ballistic Missile Treaty of 1972', 14 Dec. 2001, URL <http://www.iss.niiit.ru/sobdog-e/sd-67.htm>.

Russia's relatively mild reaction to the US withdrawal from the ABM Treaty could be explained by the progress the sides had achieved in the area of further strategic arms reductions.[34] During the November 2001 Russian–US summit meeting, President Bush announced the willingness of the USA to reduce its strategic nuclear arsenals to a level of 1700–2200 deployed warheads—or about 10 per cent below the ceilings which the Clinton Administration had agreed—within a decade. In addition, the idea of formalizing the reductions on, as President Bush described it, 'a sheet of paper' was accepted.[35] During the visit of Secretary of State Colin Powell to Moscow in mid-December, the two sides agreed to codify the nuclear reductions in an agreement, although the form of such an accord would have to be negotiated.[36] For the first time, Powell said that it might take the form of a treaty, which the Bush Administration had previously resisted. Both presidents issued instructions to have the new arms control accord ready to be signed during President Bush's state visit to Moscow in late May 2002. Russia and the USA agreed to begin talks at the expert level in January 2002 on the levels of strategic nuclear reductions and the transparency and verification measures to be applied.[37]

III. Three scenarios for developing nuclear transparency

Three scenarios for developments in the area of nuclear transparency may be envisaged, depending on the course of the Russian–US strategic dialogue after the signing in May 2002 of the Treaty on Strategic Offensive Reductions (to be ratified).

In the first, a worst-case scenario, the follow-on Russian–US strategic nuclear consultations will fail. Under this scenario, existing transparency regimes could be significantly affected. The START I verification provisions would be frozen, with uncertain chances for revival. The START I Joint Commission on Inspections and Compliance would be paralysed. Regular data exchanges and various inspections would stop. Even non-interference in verification activities by NTM might be damaged. In a situation of missile defence developments in the absence of nuclear arms reduction agreements, Russia would have to accelerate activities aimed at developing technical countermeasures against missile interception. This would create a motivation to resume the encryption of telemetry data on missiles during their flight tests since these data could be used to facilitate work on the US missile defence.

[34] For a discussion of the ABM Treaty and international responses to the USA's decision to withdraw from it see Kile, S., 'Ballistic missile defence and nuclear arms control', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 70–77.

[35] 'President announces reduction in nuclear arsenal', Press Conference by President Bush and Russian President Vladimir Putin, The White House, Office of the Press Secretary, Washington, DC, 13 Nov. 2001, URL <http://www.whitehouse.gov/news/releases/2001/11/20011113-3.html>.

[36] 'Remarks by Secretary of State Colin L. Powell and Russian Foreign Minister Igor Ivanov following their meeting, The Kremlin, December 10, 2001', US State Department transcript, available at URL <http://www.acronym.org.uk/tdocs/0112/doc03.htm>.

[37] Tyler, P. E., 'US and Russia to complete talks on an arms control pact', *New York Times*, 11 Dec. 2001.

In the political environment that would be created by an effective collapse of the START I regime, it would be hard to imagine any discussions on expanding transparency into new areas, such as nuclear warheads. At best, further progress in transparency would be halted for years.

Nevertheless, even in this scenario, the bilateral transparency regime would not completely disappear. The Treaty on Open Skies would provide a means for some cooperative transparency. Russia and the USA might also decide to continue implementation of CTR projects, granting the USA limited access to many Russian nuclear facilities. If transparency measures necessitated by traditional strategic arms control agreements no longer function, the alternative assistance-for-transparency approach would become the only available mechanism for the USA to maintain on-site transparency in Russia's nuclear capabilities. This makes it likely that, despite negative momentum in bilateral relations, the USA would prefer to continue implementation of assistance programmes. Russia could also remain interested in continuing its participation in at least the most profitable project, the HEU Agreement, with its built-in transparency arrangements.

The second scenario could be seen as an optimistic one. The two sides would solve their disagreements concerning nuclear reductions beyond the Treaty on Strategic Offensive Reductions and conclude formal agreements containing *inter alia* binding transparency and verification provisions. Transparency resulting from the START I verification regime would remain in force. The two sides might also agree to expand the assistance-for-transparency approach by finalizing the Trilateral Initiative and agreeing on other measures. In this scenario, a partial return to the Helsinki package might eventually take place, especially with regard to transparency in strategic nuclear warheads, with the aim of guaranteeing irreversibility of strategic nuclear reductions. In the longer run, along with a substantial improvement of Russian–US political relations, Russia and the USA could think about negotiating transparency measures that would also apply to their tactical nuclear warheads.

The third scenario could be called the realistic one. It would be mixed: Russia and the USA would not resolve their differences but would constrain themselves from inflicting too much damage on general bilateral relations or existing arms control and other cooperative arrangements. Indeed, it appears that they have already begun to make this scenario a reality, judging from the US decision to withdraw from the ABM Treaty and Russia's relatively mild reaction to it. Although there is no clarity about the nature of the new strategic framework, the USA seems to believe that the transition could continue for five to seven years, and would be accompanied by extensive transparency and confidence-building measures.[38] The Treaty on Strategic Offensive Reductions could be followed by new transparency measures, such as regular data exchanges, recip-

[38] Remarks of Donald Rumsfeld, US Secretary of Defense, Moscow, 13 Aug. 2001, URL <http://www.hsfk.de/abm/bushadmi/rumsfeld/130801a.html>.

rocal visits or even the provision of symbolic subcontracts for Russian companies to dismantle US strategic nuclear systems. These transparency measures would probably be of an ad hoc nature, without being codified into any legally binding verification agreement.

The diminishing role for formally negotiated arms control resulting from such an approach would inevitably affect the built-in formal agreements of the existing transparency regimes. The Russian side has already hinted that it wants to streamline the START I verification regime. According to some Russian experts, the regime not only is too complicated but also requires too many different kinds of inspections. Russia is also experiencing financial difficulties in conducting the inspections of US strategic forces mandated by START I. Therefore, even before completing the START I reductions, Russia reportedly raised the streamlining issue at the 2001 talks with the USA and the two sides seem to have made progress along these lines.[39] At the same time, they are reported to have expanded the transparency regime with regard to reductions to be made beyond the START I provisions.[40] As a result of further discussions, they could agree to limit themselves voluntarily in numbers and types of START I verification activities. Most probably, the USA could try to maintain the informal nature of these 'streamlines' in order to avoid painful ratification debates in the Senate.

A mixed picture might emerge in the missile area as well. Ambiguities about US missile defence plans might force Russia, as detailed in the first scenario, to resume encryption of telemetry data during its missile flight tests. On the other hand, in order to alleviate Russia's concerns, the USA might offer Russia extensive briefings and demonstrations of its missile defence activities. In fact, the first such briefing has already been given to a high-level Russian military delegation during a visit to Washington, DC, in early August 2001.

In summary, while the third scenario could curtail formal transparency, informal transparency measures could be expanded. The major question would be whether any new measures could adequately compensate for the partial loss of existing measures. Under this scenario, since transparency would become increasingly informal, it would thus become more uncertain and more easily reversible. Nevertheless, such a mixed approach would help to limit the damage to overall Russian–US bilateral nuclear transparency, prevent political relations from seriously deteriorating, and keep the prospects open for a possible future return to more formal and solid regimes.

[39] ITAR-TASS, 18 Jan. 2002, in 'Russian official says Moscow, Washington continue to disagree on arms reductions', Foreign Broadcast Information Service, *Daily Report–Central Eurasia (FBIS-SOV)*, FBIS-SOV-2002-0118, 18 Jan. 2002.

[40] 'Response to Russian statement on US ABM Treaty withdrawal', The White House, Office of the Press Secretary, Washington, DC, 13 Dec. 2001, available at URL <http://www.whitehouse.gov/news/releases/2001/12/20011213-8.html>.

IV. Security concerns and prospects for transparency in warheads

Russia and the USA differ not only in their priorities with regard to formal bilateral strategic arms control but also in their approaches to warhead transparency. The USA has long been interested in including all Russian stockpiles of warheads, both tactical and strategic, in transparency measures. Russia preliminarily accepted transparency only in strategic warheads in an attempt to guarantee the irreversibility of reductions under a new strategic accord and to deprive the USA of rapid breakout capabilities. Historically, Russia has never expressed interest in transparency in tactical nuclear warheads and has never officially disclosed data on its tactical nuclear weapon stockpiles.

Beyond the different positions taken by Russia and the USA, pursuing warhead transparency measures meets with significant technical difficulties. In the START process the two sides destroyed delivery vehicles. Their locations were well known and verification of their dismantlement proved to be effective. However, warhead transparency would pose new problems because most warheads are stored separately from their carriers and it is therefore difficult to monitor numbers, location and transfers by NTM. There is also a fundamental dichotomy between the need to verify warhead operations reliably and the requirement to maintain secrecy concerning their designs.[41]

At the 1997 Helsinki summit meeting, Russia demonstrated its willingness to discuss transparency in strategic nuclear warheads in the context of strategic nuclear reductions below the START II level. This suggested that, if the USA were to agree to make deep reductions, Russia could accept some transparency in strategic warheads as a measure accompanying their elimination. However, several problems came to the fore. A centrepiece of the US military strategy is the maintenance of maximum flexibility in force structure, including significant hedge capabilities that would permit the reconstitution of larger deployments if deemed necessary. This philosophy contradicted Russia's interest in deep, irreversible reductions and made a deal involving strategic warhead transparency in exchange for irreversible cuts quite difficult, if not impossible.

The USA is not particularly interested in transparency agreements that involve only warheads carried on strategic nuclear delivery vehicles, since they represent a smaller portion of Russia's total nuclear arsenal. Moreover, strategic nuclear forces are shrinking rapidly and are already regulated by the START I Treaty. At the same time, however, discussions about how to increase transparency in strategic arsenals would present the USA with an opportunity to also discuss tactical nuclear warheads.

[41] For further discussion of these contradictory needs and how they might be met see chapter 8 and appendix 8A in this volume.

Divergent interests in transparency for tactical nuclear weapons

The prospects for establishing transparency in tactical nuclear warheads remain slim. In the 1990s Russia was reluctant to codify tactical nuclear arms control measures into legally binding agreements. This prevented Russia and the USA from moving towards warhead transparency in the most direct way, through the negotiation of a verification regime for future tactical nuclear arms control agreements.

Russia's position is generally explained by several factors, principally the increasing perceived utility of nuclear weapons in Russian military thinking.[42] Indeed, in the 1990s Russia allocated very limited resources to national defence and will therefore have to reduce the size of its armed forces from the level of 2.7 million in 1992 to 850 000 by 2003.[43] These reductions would be possible because its growing conventional inferiority has been compensated by its still sizeable nuclear capabilities, seen as relatively inexpensive and powerful equalizers, providing credible guarantees against traditional non-nuclear aggression. If the current trends persist, nuclear weapons might play a greater role in deterring not only NATO and China but also regional powers. According to recent plans, Russia's ground forces will be reduced to a level of 170 000, some of whom are already dispersed among more than half a dozen peacekeeping missions, from Sierra Leone to Tajikistan. This manpower might be insufficient for dealing with the conventional might of some medium powers to the south of Russia. Therefore, tactical nuclear weapons could acquire regional functions—to provide security guarantees for Russia's allies in Central Asia and Armenia.

When the three Baltic states join NATO, the significance of tactical nuclear weapons could increase further unless NATO–Russian relations have improved radically. The new enlargement of NATO is likely to give rise to fresh concerns about the survivability of Russia's tactical nuclear weapons. These weapons might become a target for a conventional disarming strike, which could be carried out within minutes if the territories of the new members located along Russia's western border were to be used. This concern about pre-emptive vulnerability will, in turn, reinforce Russia's reluctance to agree to measures aimed at enhancing transparency in tactical nuclear weapons.

The Russian military question the very principle of equal levels of tactical nuclear weapons for Russia and the USA, citing the different geo-strategic environments of the two countries. The USA has no potential adversary in its neighbourhood and thus no need for such weapons in the context of deterrence. In contrast, Russia is located between many dynamic, strong and aspiring

[42] Russian Ministry of Defence, 'Russia's military doctrine', *Arms Control Today*, vol. 30, no. 4 (May 2000), pp. 29–38.

[43] Arbatov, A., [Security—Russia's choice] (Episentr: Moscow, 1999), pp. 430, 434 (in Russian).

powers in Europe and in Asia and might also be directly challenged by nuclear and missile proliferators.[44]

Moreover, Russian weapons of this category cannot reach the US homeland and overall ceilings on their numbers could hardly bring benefits to US forces overseas. As mentioned above, the USA is interested in tactical warhead transparency in order to prevent, or at least monitor, leakages and gain higher certainty for force planning purposes. Codifying the PNIs—with accompanying transparency measures—could also be helpful for guaranteeing the present low-alert status of Russian tactical nuclear weapons,[45] avoiding the risk of their unauthorized launch and maintaining regional stability in Europe.

For economic reasons, it will be difficult in the long run for Russia to maintain high levels of tactical nuclear deployments. Russia might therefore have an incentive to eventually accept transparency in its tactical nuclear warheads in exchange for benefits in some other areas. Such a deal could be made in some form of arms control agreement which would include warhead transparency measures. The 1997 package of agreements showed that this is not an impossible undertaking.

Russia, for its part, is interested in preventing the deployment of tactical nuclear weapons on the territories of the new NATO member states. In the framework of the 1997 package, which helped to reconcile Russia to the first wave of NATO enlargement, NATO stated that it had no plans or intentions to deploy nuclear weapons in the new member states. This provision was also included in the 1997 NATO–Russia Founding Act on Mutual Relations, Cooperation and Security.[46] Despite the importance of these statements, the NATO non-deployment pledge is not legally binding and thus reversible. In the mid-1990s, Russia attempted to codify this obligation in a treaty by proposing—via its ally, Belarus—the establishment of a Central European nuclear weapon-free zone (NWFZ). It was proposed that the treaty zone of application include the former Warsaw Pact Central European countries as well as the newly independent states located to the west of Russia.[47] It was even hinted that, under certain circumstances, Russia's Kaliningrad *oblast* could also be incorporated into the NWFZ.

At that time, the idea was received relatively positively by the East European newly independent states but was rejected by the Central European states applying for NATO membership and leading NATO countries.[48] They claimed that

[44] Belous, V., [Prospects for controlling tactical nuclear weapons], *Yadernoye Rasprostraneniye*, no. 37 (Carnegie Moscow Center: Moscow, Oct./Dec. 2000), (in Russian).

[45] The majority of Russia's tactical nuclear warheads are kept in central storage sites and are not deployed with their delivery vehicles.

[46] 'The member States of NATO reiterate that they have no intention, no plan and no reason to deploy nuclear weapons on the territory of new members, nor any need to change any aspect of NATO's nuclear posture or nuclear policy—and do not foresee any future need to do so.' (Article IV). The text of the Founding Act is reproduced in *SIPRI Yearbook 1998: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 1998), pp. 168–73.

[47] Rozanov, A., 'Towards a nuclear-weapon-free zone in Central and Eastern Europe', *The Monitor*, vol. 2, no. 4 (fall 1996), pp. 19–21.

[48] Burgess, L., 'Nuclear policy battle looms as NATO expansion nears', *Defense News*, 30 Mar.–5 Apr. 1998, p. 42.

the NWFZ would create two zones of different security within the alliance—greater security for old members and less security for new members. However, in 1996 the USA privately indicated that in exchange for increased transparency in Russian tactical nuclear stockpiles it might be willing to agree to more binding arrangements. However, because of the interruption brought about by the US presidential election campaign and the ill will in Russia resulting from NATO enlargement, the idea failed to be seriously pursued.

Russia later attempted to address this issue from two angles. It argued that, while it had withdrawn all its nuclear warheads to its national territory, the USA had not done enough in exchange and thus remained the only nuclear power deploying its warheads on the territories of foreign nations—on the territories of its NATO allies. On several occasions, Russia appealed to the USA and put pressure on it to withdraw those warheads.[49]

Russia raised the issue of forward-based nuclear weapons during the Russian–US START III consultations held in 1997–2000. Historically, this had been a serious stumbling block, for example, during the SALT process in the 1970s, until the USSR decided to remove it from the negotiations agenda. However, Russia might now reasonably argue that its geo-strategic environment has changed dramatically. Russia has lost its conventional predominance in Europe and the system of two major alliances collapsed with the end of the Warsaw Pact. The disintegration of the USSR has meant a drastic reduction in the strength of the Russian defence forces, thus opening its key security assets to increased vulnerability. Under such circumstances, even a modest US forward-based nuclear presence has become strategically important.

All these factors might provide a framework for a deal involving transparency measures for tactical nuclear warheads. It is possible that Russia might agree on transparency for a part of its tactical nuclear forces, located in a certain area, in exchange for binding obligations from NATO on nuclear and significant conventional non-deployments to the east of the Elbe River and on the complete withdrawal of US tactical nuclear weapons from Europe. These arrangements could be accompanied by transparency measures verifying the absence of nuclear warheads from Central and Eastern Europe, withdrawal of US weapons from Western Europe and Turkey, and the storage of Russian warheads in central storage sites in European Russia.

VI. Conclusions

Until the late 1990s bilateral transparency in Soviet/Russian–US nuclear relations gradually increased. Major breakthroughs were achieved in the late 1980s and early 1990s, when the INF and START I treaties introduced unprecedented provisions for verifying compliance with formal nuclear arms control agreements. After the end of the cold war, Russia and the USA attempted to establish

[49] Yurkin, A., 'Russian official emphasizes negotiations for pull-out of US non-strategic weapons in Europe', ITAR-TASS, 14 Nov. 2002, in FBIS-SOV-2000-1114, 14 Nov. 2000.

an alternative set of transparency measures through various CTR programmes. In the early 2000s, several bilateral nuclear transparency arrangements are in place for strategic and intermediate-range nuclear delivery vehicles and for a part of the sensitive fissile materials in Russia.

Because of the increasing asymmetries in Russian–US nuclear forces and the post-cold war nature of their relations, formal bilateral nuclear arms control has partially lost its importance for both states and a deadlock has resulted. The future of arms control has become uncertain. This might lead to a loss of the essential mechanisms for further expansion of nuclear transparency measures. The recent attempts by Russia and the USA to proceed towards a new strategic framework are accompanied by significant uncertainties in their new dialogue, including the fate of existing and future transparency regimes. It is very likely that existing arrangements, imposed by formal bilateral arms control agreements, will be dismantled—in cooperative or non-cooperative ways—while new, more informal transparency measures have yet to be developed. There is a strong chance that such arrangements might be of an ad hoc nature and thus not sustainable and, indeed, easily reversible.

As a result, the regulatory and stabilizing role of arms control agreements and associated transparency could be lost. Deterrence still plays a major role in Russian–US nuclear relations, and the size of their nuclear forces will remain comparable for several years. When this approximate parity is lost during this or the next decade, as seems likely, Russia may become strongly motivated to abandon whatever transparency mechanisms are then in existence.

Despite all the emerging difficulties, it is still possible to reverse the negative trends. Russia and the USA maintain an interest in bilateral interaction in the nuclear area. There is still the potential for a grand bargain entailing deep, irreversible strategic nuclear reductions coupled with transparency in warheads. However, a broader deal involving transparency in tactical nuclear warheads will hardly be possible without a radical improvement in Russian–US relations, including the resolution of recent disagreements over issues of European security.

5. US nuclear security cooperation with Russia and transparency

*David Hafemeister**

I. Introduction

This chapter reviews the efforts of Russia and the United States to conclude agreements on the control or reduction of their inventories of nuclear warheads and military fissile materials. While some of the negotiations attempted to codify arms limitation and reduction measures, others were aimed at constraining the spread of fissile materials and technologies to the non-nuclear weapon states (NNWS). A number of the negotiations had elements of both arms control and non-proliferation.

Most of the monitoring provisions contained in nuclear agreements between Russia and the USA are in the category of *transparency measures*—those that give confidence that a state is fulfilling its obligations. Some transparency measures are unilateral and are intended to enhance confidence or goodwill. *Verification measures*, on the other hand, usually require more intrusive monitoring—enough to ensure a high likelihood that parties are in compliance with a treaty—and require formal, legally binding agreements. Taken together, these measures apply to parts of the parties' nuclear weapon complexes, with the conspicuous exception of warhead facilities. Nonetheless, the joint efforts of the past decade have laid the technical groundwork for extending the scope of monitoring to warheads.

II. Early efforts to control warheads and fissile materials

Proposals for controlling and accounting for warheads and fissile materials have a long history, dating back to the first meeting of the United Nations General Assembly, in January 1946. The first General Assembly resolution established the UN Atomic Energy Commission, with the mandate to 'make specific proposals . . . for the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction'.[1] At the first meeting of this commission, in June 1946, US Representative Bernard Baruch put forward a proposal for international control with a call for the creation of an Inter-

[1] United Nations General Assembly Resolution 1 (I), 24 Jan. 1946; the resolution is reproduced in United Nations, *Yearbook of the United Nations, 1946–47* (UN: New York, 1947), pp. 64–66.

* The views expressed in this chapter are those of the author and do not necessarily reflect the views of the US National Academy of Sciences.

national Atomic Development Authority that would own or manage all nuclear activities for military applications. The proposal also called for the dismantlement of nuclear warheads under the following conditions.

> When an adequate system for control of atomic energy, including the renunciation of the bomb as a weapon, has been agreed upon and put into effective operation and condign punishments set up for violations of the rules of control which are to be stigmatized as international crimes, we propose that: (1) manufacture of atomic bombs shall stop; (2) existing bombs shall be disposed of pursuant to the terms of the treaty; and (3) the Authority shall be in possession of full information as to the know-how for the production of atomic energy.[2]

Ultimately, the Baruch Plan failed because of the irreconcilable differences between the positions of the Soviet Union and the United States during the cold war. The Soviet Union would not accept the provision for sanctions against violations without the right of a veto by the five permanent members of the UN Security Council. It also wanted a prohibition on nuclear weapons before a verification system was put in place, which the United States would not accept.

Comprehensive nuclear disarmament remained on the UN agenda, but the reliance on nuclear weapons during the cold war blocked any attempt to achieve even modest measures. With the entry into force in 1970 of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), the role of the International Atomic Energy Agency (IAEA) in monitoring the compliance of the NNWS was expanded. However, the five states formally recognized as nuclear weapon states (NWS) under the NPT were not required to accept IAEA safeguards on their nuclear facilities.[3] The international experience with implementing IAEA safeguards for non-proliferation purposes is nonetheless relevant for a number of the tasks that would be part of a comprehensive nuclear arms reduction regime.

Fissile materials and the 1967–69 dismantlement demonstration

In 1956 President Dwight D. Eisenhower proposed a ban on the production of fissile material for weapon purposes. In the following decade, the Warsaw Treaty Organization, the Western countries and many non-aligned states made similar proposals, but no serious negotiations took place.

In 1966 the USA made a proposal that was more limited but still remarkable for the times to the Conference on Disarmament (CD). Under this proposal the USA and the USSR would transfer highly enriched uranium (HEU) from weapons to peaceful uses under international safeguards. The USA offered to

[2] US Department of State, *Documents on Disarmament, 1945–1956* (US Government Printing Office: Washington, DC, 1960), pp. 10–15, available at URL <http://highered.mcgraw-hill.com/olc/dl/35265/2_3.html>.

[3] The 5 NPT-recognized NWS are China, France, Russia (formerly the USSR), the UK and the USA. The NWS make some of their civilian facilities, but not their military facilities, eligible for IAEA monitoring under Voluntary Offer Agreements.

transfer 60 tonnes of HEU under the condition that the USSR would transfer 40 tonnes to peaceful uses. Both states were expected to demonstrate 'the destruction of nuclear weapons to make HEU available for transfer to peaceful nuclear energy under international safeguards, and to halt the production of weapon-usable nuclear materials'.[4]

As part of the US Government's assessment of the verifiability of this proposal, the Arms Control and Disarmament Agency (ACDA), working with the US Atomic Energy Commission and the Department of Defense (DOD), created Project Cloud Gap for demonstration inspections of dismantlement.[5] The experiments were carried out at the Pantex (Texas), Rocky Flats (Colorado), Paducah (Kentucky) and Oak Ridge (Tennessee) facilities. Inspectors were given extensive access to the Pantex facility for close observation and monitoring of weapon dismantlement.[6] At Rocky Flats they monitored the disassembly of warhead pits and separation of materials into plutonium, uranium and other residue. At Paducah they monitored the separation of materials into salvageable categories and the disposal of classified residue. At the Y-12 plant at Oak Ridge, they monitored the disassembly of HEU parts and the melting and casting of HEU into ingots. The inspectors carried minimal equipment, such as cameras, scales, Geiger counters, portable neutron counters and gamma-ray spectrometers, and collected samples for mass spectrometer measurements of the isotopic concentrations of the materials. The experiment monitored 40 warheads undergoing scheduled disassembly, along with 32 fake warheads.

The principle behind the experiments was to provide unrestricted visual access to the dismantlement process in order to ensure that warhead dismantlement was taking place. There was no attempt to conceal classified information.[7] With this degree of open access, the ACDA report's conclusion that classified information would be revealed came as no surprise. However, the report also concluded that information 'could be protected by redesign of facilities and equipment'.[8] This project highlighted the tension between obtaining the needed degree of confidence that weapons were being destroyed and protecting sensitive information—a tension that is still central to efforts to design effective monitoring arrangements.

[4] Fisher, A. (Deputy Director, ACDA), Conference on Disarmament, *Documents on Disarmament*, 6 Mar. 1966, pp. 122–23. 'We agree first to the demonstrated destruction of thousands of nuclear weapons by the United States and the Soviet Union; second, to the transfer to peaceful purposes under international safeguards of the large quantities of fissionable material obtained from this destruction; and third to a verified halt in the production of fissionable material for weapons purposes'.

[5] Arms Control and Disarmament Agency (ACDA), 'Final Report, vol. 1. Field Test FT-34: Demonstrated Destruction of Nuclear Weapons' (Jan. 1969, released with deletions under the Freedom of Information Act). See also von Hippel, F., 'The 1969 ACDA study on warhead dismantlement', *Science & Global Security*, vol. 2, no. 1 (1990), pp. 103–108, available at URL <http://www.princeton.edu/%7Eglobsec/publications/pdf/2_1vonHippel.pdf>.

[6] ACDA (note 5), pp. 51–56.

[7] ACDA (note 5), p. 76.

[8] ACDA (note 5), p. 10.

Warhead monitoring in cold war nuclear arms control agreements

INF and START

The major agreements to limit or reduce offensive nuclear arms that were negotiated by the two superpowers during and immediately after the cold war—the SALT I and II agreements, the INF Treaty, and the START I and II treaties[9]—focused on delivery vehicles and launchers. Warheads were dealt with mainly through 'counting rules' that attributed a certain number of deployed warheads to a particular delivery vehicle, for the following reasons.

1. Ballistic missiles are the major delivery vehicle for nuclear warheads.
2. Ballistic missiles, silos, submarines and bombers are much larger and easier to count than nuclear warheads. They are also far more difficult to hide than warheads or their fissile material components. Technologies such as templates, attributes and information barriers were not available at that time to properly verify warhead dismantlement without the risk of revealing sensitive design information, and national technical means (NTM) could only assess delivery vehicle inventories. Nor were the USA and the USSR willing to accept the level of intrusiveness required to verify limits on warheads.
3. The number and characteristics of the Soviet and US deployed strategic delivery vehicles and launchers provided better measures of the strategic significance of their nuclear arsenals than the size of their warhead or fissile-material stockpiles. The traditional concerns of both states were with warheads that can be delivered rapidly and accurately over long distances, although delivery by aircraft, ships and trucks was also a concern.
4. Modern strategic delivery vehicles are expensive, typically costing the USA, for example, 10 times more to develop, produce and maintain than the nuclear warheads they carry. The elimination of delivery vehicles therefore created a greater barrier to reconstituting deployable nuclear weapons.

The INF and START treaties nonetheless contain provisions relating to warheads.[10]

The INF Treaty preceded the winding down of the cold war.[11] It was the first Soviet–US agreement to eliminate an entire class of nuclear weapons, banning the possession and deployment of ground-launched missiles with ranges of 500–5500 kilometres. In carrying out its INF obligations, the USSR destroyed

[9] The 1972 SALT I Interim Agreement, the 1979 Treaty on the Limitation of Strategic Offensive Arms (SALT II), the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty), the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I), and the 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms (START II, not in force; on 14 June 2002, as a response to the expiration of the ABM Treaty on 13 June, Russia declared that it will no longer be bound by the START II Treaty).

[10] The provisions of the START treaties are discussed in section III.

[11] *The INF Treaty*, US Senate Executive Report 100-15 (US Government Printing Office: Washington, DC, 14 Apr. 1988).

1800 missiles, capable of carrying over 3000 warheads, and the USA destroyed 850 single-warhead missiles.[12]

One of the most important verification issues was the need to determine that the banned SS-20 missile was no longer deployed by the Soviet Union.[13] This was difficult, because the first stages of the permitted long-range (strategic) SS-25 intercontinental ballistic missile (ICBM) and the prohibited intermediate-range (theatre) SS-20 missile are similar.[14] In addition, because SS-25 canisters are larger than SS-20 canisters, an SS-25 canister could contain an SS-20 missile.

The problem was further complicated by the Soviet deployment of SS-25s at some former SS-20 bases. SS-25s have one warhead and SS-20s have three, so the patterns of neutron and gamma-ray emissions from the plutonium in the warheads are different for the two systems. Under the INF Treaty, this difference could be measured with radiation-detection equipment, which measures the flux of neutrons while the missile is in its canister but gives no critical information on warhead design.[15] Under the INF Treaty the parties had the right to establish a permanent continuous monitoring system. The USA built a perimeter-portal continuous monitoring (PPCM) system at the Soviet Votkinsk Machine Building Plant, 500 km east of Moscow,[16] and the USSR monitored the US Hercules Plant Number 1 at Magna, Utah, where Pershing II rocket engines were produced. The PPCM monitoring facility operated at Votkinsk for the duration of the treaty, from 1988 to 2001. Under the INF Treaty inspectors could measure the length and weight of all objects entering and leaving the missile factory. All road and rail shipping containers large enough to hold an SS-20 missile were made available at Votkinsk for X-ray imaging with a modified version of a commercial scanner, the CargoScan. The X-ray images showed the length and diameter of the first stages of the missiles to ensure that they were not SS-20 first stages. In addition, inspectors could visually inspect and measure a missile inside its canister eight times a year. This random inspection of canisters provided a great deterrent to cheating. US inspectors also patrolled the 5-km perimeter fences around Votkinsk.[17]

[12] *The START Treaty*, US Senate Executive Report 102-53 (US Government Printing Office: Washington, DC, 18 Sep. 1992). Under the INF Treaty, the USSR destroyed 654 SS-20 missiles capable of carrying 3 warheads each. In addition, the SS-4, SS-5, SS-12, SS-20, SS-23 and SSC-X missiles were destroyed. The USA destroyed 169 Pershing 1As, 234 Pershing IIs and 443 ground-launched cruise missiles.

[13] Harahan, J. P., *On-Site Inspections Under the INF Treaty* (US On-Site Inspection Agency: Washington, DC, 1993), p. 145.

[14] Strategic nuclear weapons are those with intercontinental range (>5500 km); theatre (also called tactical or non-strategic) nuclear weapons have less than intercontinental range (<5500 km).

[15] Ewing, R. I. and Marlow, K.W., 'A fast-neutron detector used in verification of the INF Treaty', *Nuclear Instruments and Methods in Physics Research*, vol. A299 (1990), pp. 559–61. The detailed procedures for carrying out inspections with radiation detection equipment were too complex to negotiate into treaty language, so it was left to the INF Standing Verification Commission (SVC) to establish inspection procedures. The SVC agreed on the use of fast neutron detectors to determine the spatial pattern of radiation outside of canisters for field inspections.

[16] Harahan (note 13), p. 67.

[17] Similarly, the START I Treaty permitted the USA to build a PPCM at the Pavlograd plant in Ukraine, where the SS-24 ICBM was built, and permitted the USSR to build a PPCM at Promontory,

The Slava experiment

On 5 July 1989 a team of Soviet and US scientists measured the gamma-ray spectra from a Soviet warhead mounted on an SS-N-12 cruise missile on the *Slava* cruiser with a high-purity germanium detector.[18] The most detectable gamma transitions showed the presence of uranium-235, plutonium-239 and uranium-232. The presence of uranium-232 indicated that the uranium in the Soviet warhead had resided in a nuclear reactor before being used as feedstock for an enrichment plant. The data also showed a transition, which the investigators interpreted as being induced by inelastic neutron scattering on the iron missile-support structure.[19] Another transition was interpreted as coming from the absorption of neutrons by hydrogen. This was consistent with the considerable amount of hydrogen in the missile fuel and in the high explosives around the nuclear weapon.

The Soviet–US team also monitored neutron emissions from the warhead on the *Slava*.[20] A helicopter carrying neutron detectors flew at a distance of 30–80 metres from the warhead. The detectors were designed to observe a warhead at distances of 100–150 metres with the requirement that the signal must be more than three times the standard deviation (σ) of the background. The neutron data from the passage of the helicopter at 30 metres were about two to three times greater than the 3σ-background level.

III. Major post-cold war initiatives

The end of the cold war offered both great hope and great danger. Soviet/Russian and US leaders saw an opportunity to transform their relationship from a hostile to a cooperative one, reducing the risks that the two states' nuclear arsenals had posed to each other's forces and homelands, and to international security more broadly. The collapse of the Soviet Union also brought fears concerning the security of thousands of nuclear warheads and tonnes of fissile materials and the proliferation risks of 'loose nukes'.[21] In responding to these risks and opportunities, leaders in Russia and the USA undertook remarkable

Utah, where the Peacekeeper ICBM was built. A PPCM facility houses *c.* 30 inspectors and costs about $10 million per year.

[18] Fetter, S. *et al.*, 'Gamma-ray measurements of a Soviet cruise-missile warhead', *Science,* vol. 248, (1990), pp. 828–34.

[19] The gamma-ray detector had a resolution of 2 kilo-electronvolts (keV) (full-width at half-maximum) at 1000 keV, with a diameter of 5.9 cm and a length of 5.9 cm. The gamma-ray spectra from the weapon were measured for 24 minutes, followed by measurements of an empty missile tube for 10 minutes. Background measurements were carried out for 70 minutes. Inelastic collisions with neutrons can create gamma rays from excited states of stable nuclei. When fast neutrons collide with iron-56 nuclei, they can excite the 846.9 keV state of iron-56 while reducing the amount of total kinetic energy.

[20] Belyaev, S. *et al.*, 'The use of helicopter-borne neutron detectors to detect nuclear warheads in the USSR–US Black Sea Experiment', eds F. von Hippel and R. Sagdeev, *Reversing the Arms Race: How to Achieve and Verify Deep Reductions in the Nuclear Arsenals* (Gordon and Breach: New York, 1990), pp. 328–33.

[21] Campbell, K. M. *et al.*, *Soviet Nuclear Fission: Control of the Nuclear Arsenal in a Disintegrating Soviet Union,* Belfer Center for Science and International Affairs, BCSIA Studies in International Security no. 1 (Harvard University: Cambridge, Mass., Nov. 1991).

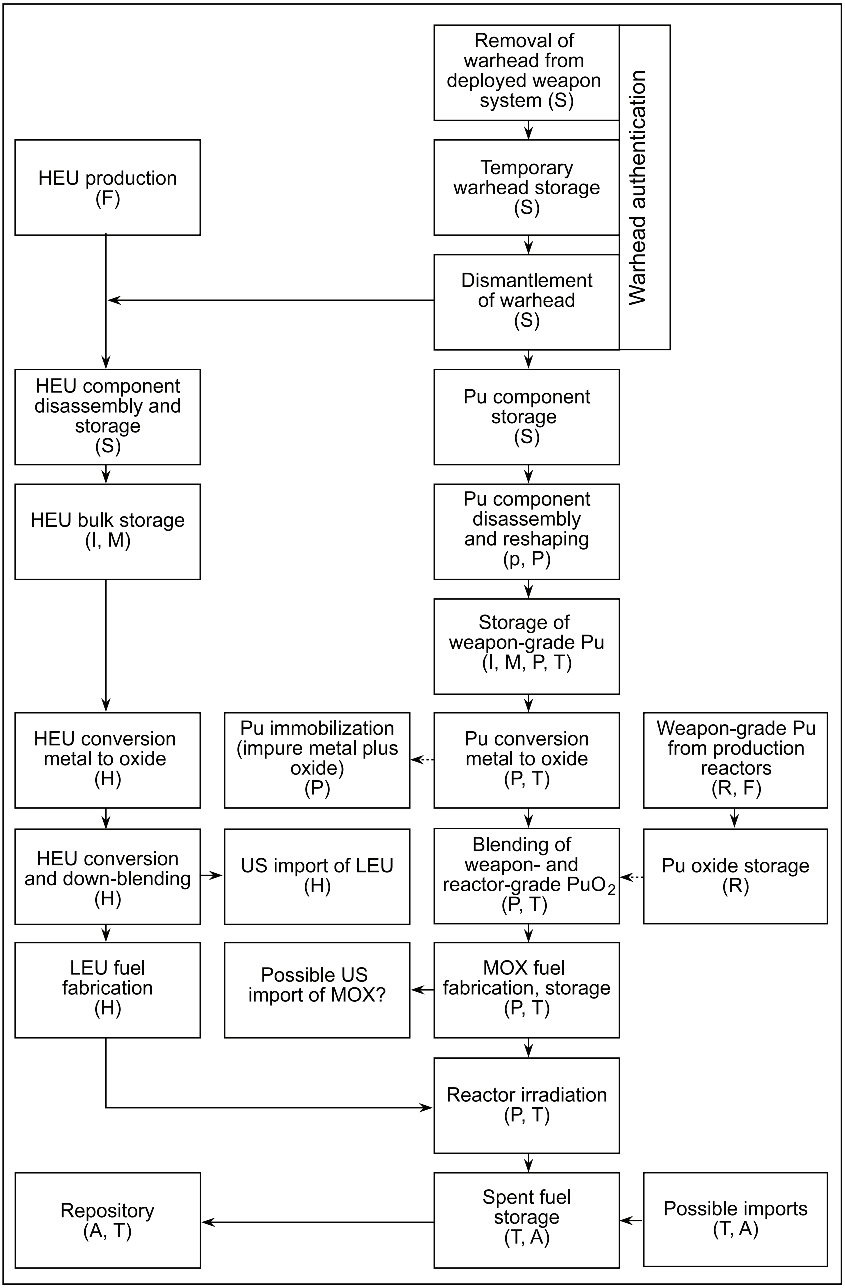

Figure 5.1. Diagram of the Russian nuclear weapon cycle and Russian–US monitoring requirements

HEU = highly enriched uranium; LEU = low-enriched uranium; MOX = mixed oxide fuel; Pu = plutonium; PuO_2 = plutonium dioxide.

Existing monitoring requirements: H = 1993 HEU Agreement; I = IAEA Voluntary Safeguards on select nuclear explosive materials (NEM), (in the process of ratification).

Monitoring requirements under discussion between Russia and the USA: A = Agreement for Cooperation for Russian Spent Fuel Repository (under discussion); F = Fissile Material Cut-off Treaty (first discussed in 1993, intermittently since then); M = 1996 Mayak Storage Facility Transparency Agreement; p = Processing and Packaging Implementation Agreement (discussed in 1997–99); P = 2000 Plutonium Disposition and Management Agreement (not in force); R = 1997 Agreement concerning Cooperation Regarding Production Reactors; S = START III accord (discussed in 2000); T = Trilateral Initiative (proposed in 1996, under discussion).

This figure represents the Russian cycle for the dismantlement of nuclear warheads and final disposition of excess NEM. (It should be noted that the US cycle is slightly different.) The figure does not show the re-manufacture of nuclear warheads, monitoring of deployed warheads under START or elimination of strategic nuclear delivery vehicles and launchers. Nor does it include the possibility of Russian reprocessing of US-origin spent fuel, but it does consider the possibility of the US import of Russian MOX.

Source: Adapted from Doyle, J. and Seitz, S., 'Applied monitoring and transparency initiatives for nuclear weapon fissile materials reductions', *Proceedings of the 42nd Annual Meeting of the Institute for Nuclear Materials Management (2001)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

initiatives that have provided at least the basic foundations for much more cooperative and comprehensive arrangements to control nuclear warheads and materials. Figure 5.1 illustrates the sequence and context of the numerous technical and diplomatic initiatives and efforts in relation to different parts of the complex Russian nuclear weapon cycle.

Unilateral initiatives

Non-strategic nuclear weapons

In 1991 President George H. W. Bush announced the withdrawal of all US ground- and sea-launched tactical nuclear weapons to the USA. All of the ground-launched and about half of the sea-launched weapons would be destroyed. Soviet President Mikhail Gorbachev responded with the announcement that all Soviet tactical nuclear weapons would be withdrawn to the Russian Federation, and that nuclear artillery, ground-launched missile warheads and nuclear mines would be destroyed. In 1992 Russian President Boris Yeltsin confirmed and extended Gorbachev's pledges. In addition to destroying all ground-launched tactical warheads, he announced that Russia would destroy half of its air-launched tactical warheads, half of its nuclear warheads for anti-aircraft missiles and one-third of its tactical sea-launched nuclear warheads. Full implementation of the pledges in the 1991–92 Presidential Nuclear Initiatives (PNIs) would mean that approximately 5000 US tactical warheads would be destroyed.[22] The number of Russian warheads scheduled for destruction is more difficult to judge; the US Central Intelligence Agency gave an estimate of

[22] Excerpts from the PNIs are reproduced in *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), pp. 85–92.

5000–15 000 warheads.[23] Under the PNIs, the unilateral reductions were not subject to monitoring, nor were there meaningful transparency measures. It is therefore not known whether the reductions were carried out completely.

Fissile materials

The end of the cold war left Russia and the USA with large stockpiles of plutonium and HEU, far more than they could possibly need for nuclear weapon production or maintenance of stockpiles. Both governments gradually came to the conclusion that continued production of fissile material was unnecessary, and they took unilateral action during the late 1980s and early 1990s to close down the fissile material manufacturing facilities which were still in operation.[24] After the accident at the Chernobyl nuclear power facility in 1986, there was widespread public concern, particularly in the USA, about the environmental hazards associated with nuclear energy in general and plutonium production in particular. The resulting public pressure added further impetus to the decision to stop the production of fissile material.[25]

In the USA the process of closing production facilities extended over more than two decades. Production of HEU for weapons ceased in 1964, although production of HEU continued for naval and research reactors until 1988.[26] The US Government announced in November 1991 that all HEU production would be suspended. Plutonium production reactors were closed beginning in 1964 as new reactor designs went on-line and as the need for plutonium diminished. The last two operating production reactors, located at Savannah River, South Carolina, were closed in 1988 because of safety concerns. The House of Representatives passed an amendment to the Defense Department budget in July of the following year urging the president to negotiate with the Soviet Union a bilateral ban on fissile material production for warheads. Finally, in July 1992 President Bush announced that, as part of a non-proliferation initiative, the USA would no longer produce fissile material.[27]

The Soviet Union stopped the production of weapon-grade uranium in 1988 and of plutonium in 1994 (except at three reactors).[28] President Yeltsin, reiterating an offer made earlier by Gorbachev, suggested in January 1992 that Russia and the USA negotiate a bilateral fissile material production cut-off treaty. An

[23] Gershwin, L. (National Intelligence Officer for Strategic Programs), *DOD Appropriations for FY93,* Testimony before the House Committee on Appropriations, Part 5, 6 May 1992, p. 499.

[24] Fissile material used in nuclear weapons typically consists of plutonium-239 or uranium enriched in the isotope 233 or in the isotope 235. See chapter 7, section III, in this volume.

[25] Albright, D. and O'Neill, K. (eds), *The Challenges of Fissile Material Control* (Institute for Science and International Security: Washington, DC, 1999), pp. 100–101.

[26] Grand, C., 'A Fissile Material Cut-off Treaty and the future of nuclear arms control', ed. J. Cirincione, *Repairing the Regime: Preventing the Spread of Weapons of Mass Destruction* (Routledge: New York, 2000), p. 236.

[27] Albright and O'Neill (note 25), p. 101; and Lockwood, D., 'Nuclear arms control', *SIPRI Yearbook 1993: World Armaments and Disarmament* (Oxford University Press: Oxford, 1993), p. 571.

[28] Albright and O'Neill (note 25), p. 101; and Albright, D., Berkhout, F. and Walker, W, SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997).

announcement was made that same month that Russia would stop all production of weapon-grade plutonium by 2000 regardless of whether an agreement was reached. However, the three production reactors are still operating, to provide heat and power for local residents. The Russian and US governments are working together on a plan to replace the reactors with an alternative source of energy.[29]

START: Russian–US agreements on strategic nuclear weapons

The end of the cold war enabled Russia and the USA to make genuine reductions in their strategic nuclear forces. The START I Treaty, which was signed on 31 July 1991 and entered into force on 5 December 1994, obligates Russia and the USA to limit their deployed strategic forces to 1600 strategic nuclear delivery vehicles each and 6000 treaty-accountable nuclear warheads each. START I covers only deployed strategic warheads and their delivery vehicles, not warheads after they have been removed from their delivery vehicles. START I was followed relatively quickly by the START II Treaty, signed by Presidents Bush and Yeltsin on 3 January 1993. START II contains the obligation for both signatories to ban intercontinental ballistic missiles with multiple independently targetable re-entry vehicles (MIRVed ICBMs) and to make further phased reductions to no more than 3500 deployed strategic warheads, approximately one-third of the size of the Soviet and US strategic arsenals at the time START I was signed. START II did not enter into force because of the US–Russian controversy over the future of the 1972 Treaty on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty, expired as of 13 June 2002 owing to the US withdrawal).

The START process moved beyond reliance on NTM to introduce bilateral verification measures, some of which relate to deployed strategic warheads. The total number of START-accountable missile warheads is obtained by multiplying the number of deployed missiles by the number of warheads attributed to each missile under the treaty's counting rules. The individual warheads mounted on missiles are contained in re-entry vehicles. START I permits each party 10 re-entry vehicle on-site inspections each year to verify that the number of re-entry vehicles on a selected missile does not exceed the number attributed to that type of missile. If START II had been implemented, the number of such inspections would have increased to 14 per year.

In order to prevent inspectors from gaining access to classified information, the inspected party places an opaque cover over the warheads on the missile bus. The cover has protrusions that provide space for each re-entry vehicle; the number of protrusions must be less than or equal to the attributed number of re-entry vehicles. In cases of discrepancy, the inspected party can allow the use of radiation detection equipment to clarify whether the extra object is a war-

[29] Albright and O'Neill (note 25), p. 101; and Albright, Berkhout and Walker (note 28), pp. 80, 95.

head. The US Department of Energy (DOE) has also developed radiation imaging systems to count warheads.[30]

The Biden Amendment and the START and SORT treaties

The September 1992 US Senate debate on ratification of the START I Treaty raised concerns about Russia's ability to rapidly redeploy warheads that have been removed from their delivery vehicles. There was also great concern about the security of nuclear weapons and materials. To address these concerns, an amendment proposed by Senator Joseph R. Biden, Jr was incorporated into the resolution of ratification.

Nuclear Stockpile Weapons Arrangement. Inasmuch as the prospect of a loss of control of nuclear weapons or fissile material in the former Soviet Union could pose a serious threat to the United States and to international peace and security, in connection with any further agreement reducing strategic offensive arms, the President shall seek an appropriate arrangement, including the use of reciprocal inspections, data exchanges, and other cooperative measures, to monitor (A) the numbers of nuclear stockpile weapons on the territory of the parties to this Treaty; and (B) the location and inventory of facilities on the territories of the parties to this treaty capable of producing or processing significant quantities of fissile materials.[31]

The Biden Amendment was interpreted to apply to a future START III accord, since the START II negotiations were moving to a conclusion at that time. The amendment provided a major impetus for the US Government to explore technical and policy approaches to monitoring warheads. In 2002, presidents George W. Bush and Vladimir Putin agreed to forego the START II and START III treaties. In its place, they signed the Strategic Offensive Reductions Treaty (SORT) with a limit of 1700–2200 *operational* warheads, which is the same limit as that proposed for START III, if *non-operational* submarines in maintenance are taken into account. The SORT negotiations and treaty did not consider the monitoring methods described in this volume.

[30] See, e.g., Ziock, K. P. 'Gamma-ray imaging spectrometry', *Science and Technology Review,* Oct. 1995, pp. 14–26; and Ziock, K. P. *et al.,* 'A Germanium-based coded aperture gamma-ray imager', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org. The Gamma-Ray Imaging System uses a coded aperture to preferentially absorb gamma rays. The spatial pattern of surviving gamma rays is measured and analysed to count the number of warheads. Another approach is the Radiation Pattern Identification System, which uses directionally sensitive gamma-ray detectors and a segmented neutron detector with minimal directional sensitivity. These detectors are mounted on a platform that is moved around the periphery of the missile. The intensity patterns are Fourier-analysed to count warheads.

[31] *The START Treaty*, US Senate Executive Report 102-53 (US Government Printing Office: Washington, DC, 18 Sep. 1992), resolution of ratification, p. 101.

The Cooperative Threat Reduction programme

The collapse of the Soviet Union raised fears of a loss of control over thousands of deployed strategic and non-strategic nuclear weapons and hundreds of tonnes of fissile material—the scenario for a proliferation nightmare. In the autumn of 1991 a bipartisan effort led by US Senators Sam Nunn and Richard Lugar addressed these dangers, and their proposal was passed by the Senate.[32] The legislation authorized the president to transfer up to $400 million from the appropriated defence budget for 1992, making the DOD the first major agency engaged in what became known as the Cooperative Threat Reduction (CTR) programme. US assistance for CTR and other programmes totalled $5.5 billion in the 1990s.[33]

In the early years, the CTR programme focused on assisting Belarus, Kazakhstan and Ukraine in their efforts to return all former Soviet nuclear warheads on their territories to Russia and to dismantle or destroy the associated strategic nuclear delivery vehicles and silos. It also provided assistance to Russia to eliminate strategic nuclear arms on its territory. Altogether, the programme facilitated the dismantlement of over 2000 former Soviet strategic missiles and launchers.[34] It also contributed to funding the construction of the nuclear materials storage facility at Mayak.[35] The CTR programme has funded such diverse activities as the provision of nuclear material containers, the refurbishment of Russian railway wagons for the transport of nuclear materials and the acquisition of nuclear accident response equipment.

The Russian and US governments soon recognized that the risks of theft or diversion of fissile material posed 'a clear and present danger to national and international security'.[36] Russian–US programmes were developed to improve fissile materials protection, control and accounting (MPC&A) in the former Soviet Union. These programmes were shifted from the DOD to the DOE in order to more accurately identify facilities for MPC&A upgrades and define responsibilities for the participating organizations.

The CTR programme was a remarkable initiative undertaken in response to extraordinary circumstances. Engaging directly in programmes to ensure the security of nuclear warheads and fissile materials gave the USA unprecedented

[32] Coombs, R., 'US domestic politics and the Nunn–Lugar program', eds J. M. Shields and W. C. Potter, *Dismantling the Cold War: US and NIS Perspectives on the Nunn–Lugar Cooperative Threat Program* (MIT Press: Cambridge, Mass., 1997).

[33] US General Accounting Office (GAO), *Nuclear Proliferation: Coordination of US Programs Designed to Reduce the Threat Posed by Weapons of Mass Destruction*, GAO-02-180T (GAO: Washington, DC, 2001), p. 2.

[34] US Defense Threat Reduction Agency, 'Fact sheet on cooperative threat reduction', Jan. 2002. The dismantled systems included 443 ICBMs, 409 ICBM launchers, 87 bombers, 483 air-launched cruise missiles, 209 submarine-launched ballistic missiles (SLBMs) and 368 SLBM launchers on 21 nuclear-powered ballistic-missile submarines.

[35] US General Accounting Office (GAO), *Weapons of Mass Destruction: Effort to Reduce Russian Arsenals May Cost More, Achieve Less than Planned*, GAO/NSIAD-99-76 (GAO: Washington, DC, 1999).

[36] National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994), p. 1.

access to Russian facilities. Despite the difficulties involved in the implementation of many of its programmes, CTR nonetheless represents an essential part of the foundation for more comprehensive limits.

Laboratory-to-laboratory programmes

Not surprisingly, the implementation of new programmes proved slow, given the long tradition of secrecy in the Russian nuclear complex. To circumvent these difficulties and to take advantage of the potential to build trust through direct contacts between scientists, the DOE's national laboratories and their Russian counterpart institutions initiated a wide variety of contracts for joint research on technologies for the monitoring, physical security and accountancy of nuclear weapons and materials.[37] Established in 1999, the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the DOE, now has responsibility for the DOE's cooperative security programmes, including MPC&A.

The laboratory-to-laboratory contracts are intended to transfer successful technologies between the parties in order to enhance transparency and arrive at the best monitoring options. The activities are wide-ranging and include: (*a*) physical security and containment of facilities; (*b*) radiation detection techniques; (*c*) fissile material accounting; (*d*) plutonium disposition in general; (*e*) plutonium storage at Mayak; (*f*) purchase of Russian HEU; and (*g*) monitoring warhead dismantlement.

To illustrate the range of activities, over 50 contracts involving warhead dismantlement transparency have been implemented by scientists at the US DOE and the Russian Ministry of Atomic Energy (Minatom). They have involved radiation measurements, computer modelling of dismantlement facilities and measurements to confirm the removal of high explosives from nuclear weapons.

The participating laboratories in the USA are the DOE nuclear weapon laboratories (Los Alamos, Livermore and Sandia) and other DOE laboratories (Argonne, Brookhaven, Oak Ridge/Y-12, Pacific Northwest and Pantex). About 12 Russian laboratories participate, including the All-Russian Scientific Research Institute of Experimental Physics in Arzamas-16 (Vserossiyskiy Nauchno-Issledovatelskiy Institut Experimentalnoy Fiziki, VNIIEF), the All-Russian Scientific Research Institute of Technical Physics in Chelyabinsk-70 (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF), and the All-Russian Scientific Research Institute of Automatics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Avtomatiki, VNIIA) and the Research Institute of Pulse Technique (RIPT), both in Moscow.

In general, the laboratory-to-laboratory exchanges have helped the technical experts of both states to become familiar and confident with monitoring techniques and information barriers. For example, cooperative gamma-ray mea-

[37] Bieniawski, A. and Irwin, P., 'Overview of the US–Russian laboratory-to-laboratory warhead dismantlement transparency program: a US perspective', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

surements of classified objects were carried out without releasing classified information. Many believe that such programmes progressed successfully because they developed away from the political spotlight and engaged technical experts who shared both knowledge and an appreciation of the issues at the technical level.

IV. The 1990s: initiatives to limit warheads and fissile materials

In order to carry out the broad initiatives put forward for the control and reduction of nuclear weapons and stockpiles and to take advantage of the results, specific proposals and programmes for Russian–US activities were implemented in the 1990s.[38] This section outlines some of the most important programmes. It does not cover them all; for example, the important programmes that sought to provide support and alternative employment for Russian nuclear scientists and alternative, commercial activities for the former closed nuclear cities are only mentioned briefly.[39]

The programmes are discussed under four headings: (*a*) the diplomatic framework; (*b*) the production and disposition of fissile material; (*c*) the improvement of fissile material MPC&A; and (*d*) the monitoring of warheads.

The diplomatic framework

Agreements for cooperation

Beyond the formidable, but less formal, barriers raised by strong traditions of secrecy in nuclear matters, any serious effort to increase transparency in the Russian and US nuclear warhead and fissile material inventories must overcome significant legal hurdles in each state. In the USA, the Atomic Energy Act

[38] There are many accounts and assessments of this period. See, e.g., Bunn, M., *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Carnegie Endowment for International Peace: Washington, DC, and Harvard University: Cambridge, Mass. 2000), available at URL <http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>; Goodby, J. E., 'Transparency and irreversibility in nuclear warhead disarmament', ed. H. A. Feiveson, *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons* (Brookings Institution Press: Washington, DC, 1999), pp. 171–92; Thomson, D. B., *A Guide to Nuclear Arms Control Treaties*, LA-UR-99-3173 (Los Alamos National Laboratory: Los Alamos, N. Mex., July 1999); Office of Under Secretary of Defense (Acquisition, Technology and Logistics), US Department of Defense, *Arms Control Program Plan, Fiscal Years 2000-2001* (DOD: Washington, DC, 7 July 2000); Bukharin, O. and Luongo, K., *US–Russian Warhead Dismantlement Transparency: The Status, Problems, and Proposals*, PU/CEES-314 (Center for Energy and Environmental Studies, Princeton University: Princeton, N.J., Apr. 1999); Bukharin, O., Bunn, M. and Luongo, K., *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Russian American Nuclear Security Advisory Council: Princeton, N.J., Aug. 2000); and Luongo, K. N., 'The uncertain future of US–Russian cooperative nuclear security', *Arms Control Today,* vol. 31, no. 1 (Jan./Feb. 2001), pp. 3–10.

[39] More detailed accounts of these programmes can be found in Bunn (note 38); Desmond, W., 'What is the Nuclear Cities Initiative?', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30); Schweitzer, G. E., *Swords into Market Shares: Technology, Economics and Security in Russia* (John Henry Press: Washington, DC, 2000); and US General Accounting Office (GAO), *Nuclear Proliferation: Concerns with DOE's Efforts to Reduce the Risks Posed by Russia's Unemployed Weapons Scientists*, GAO/RCED-99-54 (GAO: Washington, DC, Feb. 1999).

of 1954 prohibits the release of restricted data and the sharing of such data with other states, except for mutual defence purposes. The DOE must negotiate a formal bilateral Agreement for Cooperation in order to share restricted data with a state with which the USA does not have a mutual defence agreement. The DOD and the DOE share the classification authority for information on the basing of nuclear weapons and other related matters.[40]

To support the initiatives of the early 1990s, the fiscal year (FY) 1993 and 1994 Defense Authorization Acts amended the Atomic Energy Act, granting authority to negotiate an Agreement for Cooperation with Russia to allow the sharing of limited amounts of national security information as mutually agreed by the parties to be useful for monitoring arrangements. This provided the legal basis for an ambitious effort to create broad transparency between the two states. It should be noted that Russia's nuclear exports and imports could also cause complications for the legal completion of an Agreement for Cooperation. Section 129 of the Atomic Energy Act requires that the president must determine whether Russian nuclear exports can assist the nuclear weapon programmes of other states, such as India and Iran.[41] The Iranian Government intends to complete the unfinished German nuclear power plant in Bushehr that was begun under the Shah. In 1992 Russia agreed to finish the Bushehr plant and in 1995 agreed to build a new commercial nuclear power plant for Iran with water–water power reactors, the VVER-1000 (Vodo-Vodyanoy Energeticheskiy Reaktor). The export of commercial, non-military reactors is permitted under the NPT, but the US Government contends that such exports provide knowledge of and access to the Russian nuclear complex that could assist Iran's alleged efforts to acquire nuclear weapons.[42] In addition, Russian fuel exports for the Indian Tarapur reactors violate the provision of the 1978 Nuclear Suppliers Group (NSG) Guidelines not to export to states that do not have full-scope safeguards,[43] although Russia maintains that these exports are needed for safety reasons. Finally, if Russia imports US-origin spent fuel for the proposed international spent-fuel repository, this will require an Agreement for Coopera-

[40] Habiger, E. (Commander, US Strategic Command), Department of Defense News Briefing, 16 June 1998, URL <http://www.defenselink.mil/news/Jun1998/t06231998_t616hab2.html>.

[41] Section 129 (Chapter 11) prohibits the export of any nuclear materials and equipment or sensitive nuclear technology to 'any nation or group of nations that is found by the President to have . . . assisted, encouraged, or induced any non-nuclear-weapon state to engage in activities involving source or special nuclear material and having direct significance for the manufacture or acquisition of nuclear explosive devices, and has failed to take steps which, in the President's judgment, represent sufficient progress toward terminating such assistance, encouragement, or inducement'. The Atomic Energy Act is available on the Internet site of the US Nuclear Regulatory Commission at URL <http://www.nrc.gov/reading-rm/doc-collections/
nuregs/staff/sr0980/>.

[42] Eisenstadt, M., 'Russian arms and technology transfers to Iran: policy challenges for the United States', *Arms Control Today*, vol. 31, no. 2 (Mar. 2001), pp. 15–22.

[43] The NSG Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Materials, Software, and Related Technology, as they are now called, are incorporated in IAEA document INFCIRC/254. They have been revised several times since 1978. See URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/infcirc254.shtml>.

tion with the USA as well as US consent for the reprocessing and re-transfer of spent fuel.

The Safeguards, Transparency and Irreversibility Initiative

In January 1994 presidents Bill Clinton and Boris Yeltsin agreed to establish a joint working group to consider steps to ensure the 'transparency and irreversibility' of nuclear weapon reductions. In May 1994 the working group agreed to examine options for: (*a*) declaring all stocks and locations of weapon-usable fissile material; (*b*) carrying out reciprocal inspections of storage facilities containing fissile materials removed from dismantled warheads; and (*c*) making irreversible transfers of fissile material to peaceful purposes. These terms of reference were strengthened at their September 1994 summit meeting, where they agreed to: (*a*) exchange detailed information on the aggregate stockpiles of nuclear warheads and weapon-usable nuclear materials; (*b*) develop a regular process for exchanging this information; and (*c*) direct the joint working group to develop measures to improve confidence in and increase the transparency and irreversibility of nuclear weapon reductions.[44]

The USA envisaged a transparency and irreversibility regime that provided for the exchange of detailed information and reciprocal inspections to confirm that HEU and plutonium had been removed from nuclear warheads. The regime was also intended to include cooperative measures to confirm the existence of excess warheads awaiting dismantlement as well as cooperative measures to confirm and clarify declared weapon-usable material stocks, but not to include materials in weapons or in naval fuel. In addition, the regime was to include exchange visits to the fissile material production sites and exchanges of production records.

In response to the progress of the joint Russian–US working group, presidents Clinton and Yeltsin agreed in May 1995 to negotiate agreements on the following measures: (*a*) a regular exchange of detailed information on aggregate stockpiles of nuclear warheads, on stocks of weapons-usable fissile materials and on their safety and security; (*b*) a cooperative arrangement for reciprocal monitoring at storage facilities of weapon-usable fissile materials removed from nuclear warheads; and (c*)* other cooperative measures as necessary to enhance confidence in the reciprocal declarations on fissile material stockpiles.[45] The Clinton–Yeltsin statement also declared that: (*a*) fissile materials removed from nuclear weapons being eliminated and excess to national security requirements will not be used to manufacture new nuclear weapons; (*b*) no newly produced

[44] Goodby (note 38), p. 182; and Joint Statement on Strategic Stability and Nuclear Security by the Presidents of the United States of America and the Russian Federation (The White House, Office of the Press Secretary: Washington, DC, 28 Sep. 1994), available at URL <http://csf.colorado.edu/dfax/npn/npn13.htm>. The meeting took place under the auspices of the US–Russian Joint Commission on Economic and Technological Cooperation, known as the Gore–Chernomyrdin Commission, which was established in 1993.

[45] Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons (The White House, Office of the Press Secretary: Washington, DC, 10 May 1995).

fissile materials will be used in nuclear weapons; and (*c*) fissile materials from or within civil nuclear programmes will not be used to manufacture nuclear weapons.

Although Russia and the USA appeared to be moving towards an initial regime for warhead and fissile material reductions, Russia broke off the talks in late 1995 and they were not resumed. Some US experts believe that the agenda was simply too broad and ambitious for the time and circumstances. Matthew Bunn cites three reasons for 'the transparency that never happened'.[46]

1. The historical legacy of tsarist and communist secrecy made the Russian Government 'extraordinarily reluctant to open nuclear secrets'.
2. Many in the US Government were equally unwilling to make US facilities accessible to Russia.
3. The US Government never offered significant strategic or financial incentives to overcome Russian reluctance.

Even in the absence of high-level negotiations, extensive and innovative technical discussions and experiments between Russian and US laboratories have continued as part of the laboratory-to-laboratory programme. Significant progress has been made in the joint development of approaches for monitoring warhead dismantlement and the storage of fissile components, as well as on arrangements for fissile materials. Since information barriers block the transfer of information containing restricted data, it would seem that an Agreement for Cooperation would not be needed for the collection of such data.

The production and disposition of fissile materials

General approaches

The Fissile Material Cut-off Treaty. Four of the NPT-recognized NWS have officially declared that they have stopped the production of HEU and plutonium for nuclear weapon purposes.[47] In a major initiative, the 1992 Russian–US informal agreement to ban the production of fissile materials was expanded to create the concept of a multilateral Fissile Material Cut-off Treaty (FMCT). On 27 September 1993, President Clinton proposed at the United Nations a multilateral agreement to halt the production of HEU and plutonium for nuclear explosives. In December 1993 the General Assembly adopted by consensus a resolution calling for the initiation of negotiations.[48] The January 1994 Clinton–Yeltsin summit meeting produced a joint statement calling for 'the most rapid conclusion' of the FMCT.

[46] Bunn (note 38), pp. 46–47.

[47] Grand (note 26). The cut-off dates for HEU and Pu production for weapons were as follows: France (1996/1992), Russia (1987/1994, except for 3 reactors), the UK (1963/1995) and the USA (1988/1964).

[48] United Nations General Assembly Resolution 48/75L, Dec. 1993.

The FMCT concept focuses primarily on the five NPT-recognized NWS and the three de facto NWS (India, Israel and Pakistan), but all other states would be invited to join the regime.[49] In 1995 the CD agreed by consensus to establish an ad hoc committee to negotiate a treaty, but progress stalled over a number of issues. For example, India and a few other states have declared that they would not sign an FMCT unless a strict deadline was set for the NWS to fulfil their NPT Article VI obligations to eliminate their nuclear weapons. Issues of ballistic missile defence, the weaponization of outer space (raised by China) and the no-first-use of nuclear weapons have also blocked progress. Since the CD operates on a consensus basis, a deadlock can easily be created, as happened in this case.

The cost of verifying an FMCT would vary greatly depending on the approach adopted.[50] It is unlikely that the treaty's monitoring provisions would apply to stockpiles of fissile material produced in the NWS before it entered into force. The FMCT could establish safeguards at all the power plants in the NWS, which would raise the costs since there are about as many nuclear power plants in the NWS as there are in the NNWS. However, safeguarding all reactors worldwide would not double the IAEA's burden since the IAEA also performs other tasks. It is envisaged that the IAEA would conduct routine FMCT inspections at plutonium and HEU production and storage sites in the NWS.

Precedents and experience relevant to an FMCT. A number of international arrangements offer precedents and experience that could be useful for an FMCT. A ban on the production of HEU is monitored under the 1989 Hexapartite Enrichment Project, in which six states—Australia, Germany, Japan, the Netherlands, the UK and the USA—place all their civil centrifuge plants under IAEA safeguards.[51] Monitoring to distinguish between HEU and low-enriched uranium (LEU) is an integral part of this arrangement. This type of monitoring could be extended to all types of enrichment plant. States which have nuclear-powered submarines have asked for an exemption for HEU fuels for naval propulsion. This issue could be avoided by designing the next generation of naval power plants to operate at levels well below 90 per cent uranium-235 enrichment, which several states have already done.[52]

Most of the NWS have sufficient weapon-grade plutonium, so they no longer reprocess military spent fuel. This is easy to monitor on a permanent basis

[49] Albright and O'Neill (note 25).

[50] Koyama, K., 'What the verification regime under a Fissile Material Cut-off Treaty could be like: a preliminary view', *Journal of Nuclear Materials Management,* vol. 27 (winter 1999), pp. 48–52; and Bragin, V. and Carlson, J., 'An introduction to focused approach to verification under FMCT', *Journal of Nuclear Materials Management,* vol. 28 (winter 2000), pp. 39–45. Some have speculated that the budgets needed would be about the size of the annual IAEA safeguards budget of $80 million, but this would clearly depend on the regime.

[51] von Baeckmann, A., 'Implementation of IAEA safeguards in centrifuge enrichment plants', *Proceedings of the Fourth International Conference on Facility Operations—Safeguards Interface, 29 Sep.–4 Oct. 1991* (American Nuclear Society: LaGrange Park, Ill., 1991), pp. 185–90.

[52] Ma, C. and von Hippel, F., 'Ending the production of highly enriched uranium for naval reactors', *Nonproliferation Review*, vol. 8, no. 1 (spring 2001), pp. 86–101. France uses HEU containing 90% U-235, but is switching to 7%.

when plants have been closed, but it is more complicated if the plants continue to be used to reprocess civilian spent fuel to obtain separated plutonium for fabrication into mixed oxide (MOX) fuel. The reprocessing plants in the NNWS were originally designed to accommodate IAEA material accounting measurements, but plants in the NWS were not. The monitoring of plutonium under an FMCT would also have to ensure that new plutonium remained inside the civilian nuclear fuel cycle and not in weapons. In order to obtain accurate material balances and track the material throughout its use, it would be necessary to measure flow rates at predetermined key measurement points in the plant.

In order to be confident that clandestine production of HEU or plutonium is not taking place in the NNWS, the IAEA has instituted the Strengthened Safeguards System under INFCIRC/540, by which states are required to make declarations about their research and development for enrichment and reprocessing technologies.[53] INFCIRC/540 also establishes environmental monitoring to detect clandestine plants. Special inspections under traditional INFCIRC/153-type measures already allow further inspection of a declared site to confirm declarations.[54] Special inspections can also be applied at undeclared sites. (The IAEA had requested such inspections in North Korea.) The inspection regime under INFCIRC/540 will allow managed access to undeclared facilities in order to confirm the absence of undeclared production.

Russian–US programmes and initiatives

The HEU Agreement. HEU poses a more serious proliferation danger than plutonium does since it is easier to use to manufacture nuclear warheads. HEU is not a significant spontaneous neutron emitter and can be fabricated for use in a nuclear warhead with the simpler gun-type design. At the same time, HEU has the great advantage that it can be relatively easily converted into LEU fuels that have considerable commercial value. By contrast, the use of plutonium in MOX fuels is very costly. For these basic economic reasons, significant progress has been made in reducing the Russian and US excess HEU stockpiles, while very little progress has been made in disposing of excess plutonium.

Under the 1993 HEU Agreement the USA agreed to purchase 500 tonnes of Russian HEU down-blended to LEU.[55] From June 1995 to 31 December 2002, Russia received about $2.5 billion (of the new 2002 projected $8 billion total)

[53] IAEA, Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540, Sep. 1997, and subsequent corrections, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Numbers/nr501-550.shtml>.

[54] IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), INFCIRC/153 (Corrected), June 1972, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>. Comprehensive IAEA safeguards agreements are based on this document.

[55] The text of the HEU Agreement is reproduced in *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), pp. 673–75.

for 5027 tonnes of LEU down-blended from 171 tonnes of HEU.[56] The contract value has varied over time, depending on market prices.

The USA declared 174 tonnes of its HEU as excess, with some to be down-blended into reactor fuel and some to be disposed of as waste. In addition, Minatom and the US NNSA are working together to down-blend excess HEU that resides outside of the Russian military complex. So far, the programme has down-blended 2 tonnes of HEU, with additional plans to down-blend more.[57]

The ability to monitor the weapon usability and origin of the HEU feedstock has taken time to evolve.[58] The US–Russian Transparency Review Committee has established monitoring procedures at the three relevant Russian facilities: Russian and US personnel have the right to visit processing facilities to check tags/seals, verify supporting documents, observe critical processing steps, and take measurements of uranium isotopic content and mass. The committee established the certification process for US instruments, such as the HEU/LEU Blend-Down Monitoring System.[59] The acceptance of enhanced monitoring was facilitated by a prepayment of $100 million, which gives the USA inspection privileges at Russian facilities. These inspections are necessary to assure the USA that the LEU is derived from weapon-grade HEU.

Up to 24 inspections are allowed each year along with a permanent monitoring office. Adequate set-ups for providing assurances that the uranium feedstock for down-blending comes from a weapon-grade uranium feed exist at one of the facilities, but not at the other two, where the monitoring equipment is not yet in place.[60] The FY 2001 budget for the NNSA called for monitoring equipment to be installed at Zelenogorsk in FY 2002 and for discussions to be initiated in FY 2002 on the installation of a down-blend monitoring system at Seversk in FY 2003. The USA does not monitor the complete chain of custody of HEU, from warhead to arrival at the down-blending facilities, but spot checks have given confidence that the material comes from dismantled warheads.[61]

In July 1998 the US Government purchasing agent, the US Enrichment Corporation (USEC), was privatized. This placed market considerations in conflict

[56] United States Enrichment Corporation (USEC), 'US–Russian Megatons to Megawatts Program: turning nuclear warheads into electricity (as of 31 December 2002)', URL <http://www.usec.com/>.

[57] Wander, T. *et al.,* 'Model and pilot projects on HEU consolidation and converting into LEU in SRI SIA "Luch" [Scientific Research Institute, Scientific Industrial Association 'Luch', Russian Ministry of Atomic Energy]', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[58] US General Accounting Office (GAO), *Nuclear Proliferation: Status of Transparency Measures for US Purchase of Russian Highly Enriched Uranium*, GAO/RCED-99-194 (GAO: Washington, DC, Sep. 1999).

[59] Mastal, E. *et al.,* 'Certification of US instrumentation in Russian nuclear processing facilities', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[60] Mastal, E. *et al.,* 'Current and future directions for the implementation of the US/Russian Intergovernmental Agreement: transparency and the natural feed component', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[61] GAO (note 58).

with the broader goals of arms control.[62] The HEU Agreement has been close to collapse on several occasions, but the differences have been resolved or resolution postponed.[63] Funding has been further complicated by the drop in natural uranium prices. Roughly speaking, the original price of $12 billion was based on about $8 billion for enrichment services in separative work units (SWUs) and about $4 billion for the natural uranium feed component. The spot market price for uranium dropped by more than half from 1996 to 2000, reducing the payments to Russia. About 50 per cent of the USEC's sales of LEU in the USA are from Russian imports and about 40 per cent of its total sales are Russian LEU. The implementing contract expires at the end of each year.[64] Critics of the new contract that begins in January 2003 claim that Russia is being underpaid for the uranium going into the enrichment services that are used by the USEC to keep its uneconomical Paducah plant functioning.[65] The USEC states that the $12 billion contract is now worth $8 billion because natural uranium will be returned to Russia and the market-based enrichment price will begin at $90.42 per SWU.

Management and disposition of excess weapon plutonium. Recognizing the greater proliferation risks posed by excess weapon-grade plutonium, in 1992 President George H. W. Bush's National Security Advisor, General Brent Scowcroft, asked the National Academy of Sciences to study the options for plutonium management and disposition. In a two-volume study released in 1994 and 1995, the Academy's Committee on International Security and Arms Control (CISAC) recommended that Russian and US excess weapon plutonium be converted into a form that is at least as inaccessible for weapon use as the plutonium in spent-fuel rods from civilian nuclear power production.[66] This would put weapon plutonium in the category of risks posed by spent fuel, which the CISAC also strongly recommended addressing. The CISAC determined that two approaches were acceptable to fulfil the 'spent-fuel standard': (*a*) the encapsulation of diluted plutonium in a radioactive matrix (immobilization) for eventual geological disposal with other high-level nuclear waste; and (*b*) the

[62] Neff, T., 'Privatizing US national security: the US–Russian HEU deal at risk', *Arms Control Today,* vol. 28, no. 6 (Aug./Sep. 1998), pp. 8–14.

[63] Bieniawski, A., Bussurin, Y. and Bystrov, A., 'Cooperation under the US–Russian Intergovernmental Agreement on the Disposition of Highly-Enriched Uranium from Nuclear Weapons and transparency arrangements under the HEU Purchase Agreement', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[64] United States Enrichment Corporation, 'Implementation of the US–Russian HEU Purchase Program', Hearing on Department of Energy Nonproliferation Programs with Russia, Committee on Foreign Relations, US Senate, 28 Mar. 2001.

[65] US General Accounting Office (GAO), *Nuclear Nonproliferation: Implications of the US Purchase of Russian Highly Enriched Uranium,* GAO-01-148 (GAO: Washington, DC, 2000); Neff, T., 'Decision time for the HEU deal: US security vs. private interests', *Arms Control Today,* vol. 31, no. 5 (June 2001), pp. 12–17; and Sewell, P., 'A response to Thomas Neff's "Decision time for the HEU deal"', *Arms Control Today,* vol. 31, no. 6 (July/Aug. 2001), pp. 14–16.

[66] US National Academy of Sciences (NAS), Committee on International Security and Arms Control (CISAC), *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994); and NAS/CISAC, *Management and Disposition of Excess Weapons Plutonium: Reactor Related Options* (National Academy Press: Washington, DC, 1995).

use of plutonium as MOX fuel in existing reactors without subsequent reprocessing.

To encourage the disposition of large stocks of plutonium, the two governments formed the US–Russian Joint Steering Committee on Plutonium Management. In January 1997 the DOE announced that it would use either immobilization or the MOX route for the US disposition programme. On 2 September 1998, Clinton and Yeltsin signed a joint statement of principles for the disposition of 50 tonnes of plutonium by each state using either the immobilization or the MOX approach.[67] They also agreed to develop acceptable methods for transparency measures, including international verification and stringent standards of MPC&A.

On 1 September 2000 Russia and the USA signed the Plutonium Management and Disposition Agreement (PMDA), according to which each party must remove 34 tonnes of plutonium from its nuclear weapon programme and convert it into forms that will be irreversibly removed from military purposes.[68] The agreement is to remain in effect until the plutonium is irradiated to a specified level or is immobilized for geological storage. In January 2002 the George W. Bush Administration supported the MOX disposition programme, but did not provide a budget, while it halted the immobilization programme. Although the agreement does not specify a monitoring approach, each state is responsible for accounting for its materials, with reciprocal rights of inspection and specific monitoring arrangements to be negotiated. The agreement calls for 'an appropriate arrangement' between the IAEA, Russia and the USA.[69] Uncertainties about funding in both Russia and the USA make the planning of plutonium disposition difficult.

The Mayak Storage Facility Transparency Agreement. In 1991 Minatom Minister Viktor Mikhailov stated that the former Soviet Union would need a large facility near Tomsk in which to store excess weapon-usable materials under secure conditions. In January 1996 US Secretary of Defense William Perry and Mikhailov agreed on the construction of a storage facility for excess weapon-usable fissile materials at Mayak (Chelyabinsk-65).[70]

The Mayak facility was designed in 1996 to accommodate 50 000 canisters filled with 66 tonnes of plutonium and 536 tonnes of HEU at a cost of

[67] Office of Fissile Materials Disposition, US Department of Energy, 'Record of decision issues for surplus plutonium disposition', URL <http://www.doe-md.com>. The decision allows for the disposition of 50 tonnes of plutonium—33 tonnes as MOX and 17 tonnes as immobilized waste. The 1 Sep. 2000 Russian–US agreement provides for 34 of the 50 tonnes. Holgate, L., 'US/Russian cooperation for plutonium disposition—update', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30). The programme is expected to cost about $4 billion without immobilization for the USA and $1.75 billion for Russia. The USA will contribute $200 million to assist the Russian effort and both countries plan to ask for additional assistance from the G8.

[68] The Agreement concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, 1 Sep. 2000, available at URL <http://www.ransac.org/new-web-site/related/agree/bilat/pudisp-agree.html>. The PMDA had not entered into force as of Dec. 2002

[69] Such an arrangement is being considered under the Trilateral Initiative, described in chapter 11 in this volume.

[70] US General Accounting Office (note 33), p. 8.

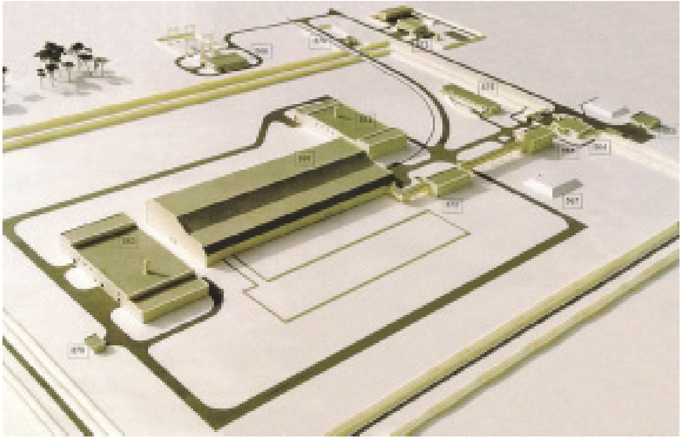

Figure 5.2. A model of the Mayak Fissile Material Storage Facility, under construction at Ozersk, Russia

Source: US Defense Threat Reduction Agency, *Technology Research and Development for Arms Control* (Office of Nonproliferation Research and Engineering, National Nuclear Security Agency: Washington, DC, spring 2001).

$275 million.[71] The first wing has been rescheduled to open in 2003 and estimated to cost about $500 million, with the USA paying 90 per cent of this sum. This wing is designed to keep 25 000 containers, holding a total of 50 tonnes of plutonium and perhaps as much as 200 tonnes of HEU.[72] A second wing of the same size could have been opened by 2010, but the $250 million in funding was not obtained.[73]

The two states agreed on 'joint accountability and transparency measures' that would permit the USA to confirm Mayak's holdings. The US Congress expects confirmation that the materials are weapon-usable, but it will be much more difficult to verify that the plutonium originated from dismantled warheads. This would require measuring the attributes of the plutonium pits when they are brought to the Russian pit processing and packaging facility for conversion into spheres or hockey-puck shapes, but this requirement appears to have been relaxed.

The draft monitoring arrangement grants the USA considerable access to the Mayak storage facility, but the type of monitoring and the number of attributes

[71] Under the Nunn–Lugar Cooperative Threat Reduction programme, the DOE spent $63 million for 32 700 canisters for Mayak. See US General Accounting Office (note 33), p. 4.

[72] HEU produces little heat and was to be used as heat spacers between the plutonium containers. The heat output from plutonium has caused some design problems, reducing storage capacity. Forced convection will be used to reduce plutonium heating.

[73] US General Accounting Office (note 33), pp. 5–7.

Figure 5.3. A crane at the Mayak Fissile Material Storage Facility, lowering fissile material into a 'nest'

Note: A nest is a cylindrical space several metres in length, in which the AT-400R canisters are stacked.

Source: US Defense Threat Reduction Agency, *Technology Research and Development for Arms Control* (Office of Nonproliferation Research and Engineering, National Nuclear Security Agency: Washington, DC, spring 2001).

to be measured have not yet been finalized.[74] The DOE is currently developing a 'single suite of equipment' for use in several monitoring arrangements.

[74] US General Accounting Office (note 33), p. 10. The technical options under consideration are addressed in chapter 11 in this volume. Russia pledges not to remove any material from the Mayak facility, other than for emergency purposes, without first negotiating provisions to assure the USA that the material would not be reused for weapons. US inspectors could monitor Mayak 6 times per year and use data from Mayak's material control and accounting system. US monitors could spend up to 5 days conducting the initial inspection. During each inspection, the monitors could download recorded data from sensors used by Russia to identify, scan and track each container as it passes through Mayak's unloading and incoming control rooms. Annually, US monitors could randomly select up to 120 storage shafts (4% of Mayak's capacity) and verify the identifying tags on containers against Mayak's records. US monitors have the right to scan 1 container from each of the selected shafts to determine its contents. Russia would be required to inventory a random number of containers twice a year with US participation.

The Plutonium Production Reactor Agreement (PPRA). Russia and the USA agreed in 1994 to stop producing plutonium and HEU for weapons. However, Russia continues to operate three plutonium-producing reactors, at Seversk and Zelenogorsk, because they supply heat and power to nearby communities. In addition, Russia has insisted that it is necessary to reprocess the spent fuel since it suffers serious corrosion problems. It was agreed that the resulting plutonium (about 1 tonne per year) would be stored in oxide form and the USA agreed to provide assistance to replace or convert these reactors so that they would no longer produce weapon-grade plutonium. According to the agreement signed by Prime Minister Chernomyrdin and Vice-President Gore on 23 June 1994, the reactors were to be closed down by 31 December 2000.[75] The plutonium produced between 1994 and 2000 was to be placed under bilateral monitoring to ensure that it would not be used in nuclear weapons. This agreement has not yet been implemented because of a failure to agree on the ultimate plans for alternatives to provide power to the communities.

The Processing and Packaging Implementation Agreement (PPIA). The implementation of the PPIA, proposed in 1997, has also faltered, but its provisions are often referred to in discussions of plutonium storage at the Mayak facility. Russian and US pits would be processed into new shapes or amorphous forms to render them unusable for weapons. The USA has considered the Advanced Recovery and Integrated Extraction System (ARIES) to convert plutonium from excess pits into oxide form. A facility for this purpose, the Pit Disassembly and Conversion Facility, was scheduled to be built at Savannah River by 2005. The ARIES operations will be unclassified once the pits are converted into plutonium oxide powder. The Russian facility at Mayak is expected to make 2-kg plutonium sphere ingots, placing two ingots in each canister. Figures 5.2 and 5.3 show a model of the exterior of the Mayak facility and the process for lowering fissile material into cylinders inside the facility, respectively. Since the ingots will be in an unclassified shape, they could be accessible to limited IAEA monitoring. However, Russia considers the isotopic ratio (Pu-240/Pu-239) to be secret and will protect it by blending plutonium stocks before measurements are allowed. The US DOD indicated that it would provide $650 million for construction of this facility, but so far Russia has rejected the offer, probably because of a need to protect classified information.[76]

A spent-fuel repository in Russia. Another approach is to build a global spent-fuel repository in Russia. A repository that could hold 10 000–20 000 tonnes of spent fuel might raise some $20 billion for Russia. The availability of such a repository could reduce the pressure to reprocess, but Russia appears to be planning to store its spent fuel for 10 years before reprocessing it to make MOX fuel. In addition, a geological repository is needed for 32 000 tonnes of US-

[75] von Hippel, F. and Bunn, M., *Saga of the Siberian Plutonium-Production Reactors*, FAS Public Interest Report 53, Nov./Dec. 2000, pp. 1–10.

[76] US General Accounting Office (note 33), p. 5; and US Department of Energy (DOE), *Warhead and Fissile Material Transparency Program Strategic Plan* (DOE: Washington, DC, Feb. 2000), pp. 12–13. The DOD would assist with transportation but not with operation and maintenance.

origin spent fuel, as there will otherwise be pressure to reprocess and thus obtain 300 tonnes of plutonium. In July 2001 President Vladimir Putin signed a law that allows Russia to import spent fuel for storage and reprocessing.[77] However, this presents many legal and political difficulties. The US Nuclear Nonproliferation Act of 1978 constrains the transfer and reprocessing of US-origin spent fuel and requires that some form of safeguards are maintained over it.[78] Russia's civil nuclear exports to India and Iran could also complicate an approval from the USA.

Improving MPC&A

The origins of the MPC&A programmes are described above. The purpose of the US programme is to help Russia with the MPC&A tools needed to strengthen its monitoring of nuclear materials. It is generally assumed that a viable transparency and monitoring plan for fissile materials and warheads would encourage the host states to improve their indigenous MPC&A programmes. The declaration and inspection processes would uncover problems which could be rectified.

The Russian HEU and plutonium that exist outside weapons are of greatest concern because these materials are subjected to the least accountancy and physical protection. The NNSA's FY 2002 budget proposal stated that 850 tonnes of military and civilian fissile materials stored at 95 sites in the former Soviet Union were probably in need of security upgrades.[79] The NNSA identified 11 Minatom sites that account for about 500 tonnes of fissile materials and 53 Russian Navy sites that contain 315 tonnes in warheads and fuel which probably need security upgrades. The civilian nuclear complex consists of 31 sites (18 in Russia and 13 in the newly independent states) which hold about 32 tonnes of material.

Because of the continuing uncertainties regarding Russia's MPC&A programme, the DOE asked the US National Research Council to review it. The Council's study concluded that there had been significant progress, but that there was much more work to be done.[80] It also concluded that the Russian

[77] Bleek, P. C., 'Russian Duma passes bill allowing import of spent fuel', *Arms Control Today,* vol. 31, no. 6 (July/Aug. 2001), p. 25; and Guinnessy, P., 'Russia banks on importing nuclear waste', *Physics Today,* vol. 54, no. 9 (Sep. 2001), pp. 24–25.

[78] McGoldrick, F., 'Proposals for an international spent fuel facility: US law and policy', Carnegie Endowment for International Peace Non-Proliferation Conference 2000, URL <http://www.ceip.org/files/events/Conf2000McGoldrick.asp?>; and Bunn, M., 'Russian import of foreign spent fuel: status and policy implications', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[79] The NNSA projected that 50% of the 95 sites would have 'comprehensive upgrades completed' by the end of FY 2002. Its projections for the end of FY 2002 were that, of 850 tonnes of fissile materials, 29% would have had 'comprehensive upgrades completed', 53% will have had 'rapid upgrades completed' and 67% will have had 'upgrades underway'. US General Accounting Office (GAO), *Nuclear Proliferation*, *Security of Russia's Nuclear Material Improving; Further Enhancements Needed,* GAO-01-312 (GAO: Washington, DC, 2001).

[80] National Research Council, *Protecting Nuclear Weapons Materials in Russia* (National Academy Press: Washington, DC, 1999); and Bukharin, Bunn and Luongo (note 38).

MPC&A programme would be a 'high-priority national security imperative for the United States for at least a decade'. The MPC&A programme addressed the following deficiencies in Russia: (*a*) a lack of unified physical protection standards and inadequate defences within sites; (*b*) a lack of perimeter-portal monitors to detect nuclear materials leaving sites; (*c*) inadequate central alarms and assessment and display capabilities; (*d*) inadequate protection of guards from weapons and an inadequate guard force; (*e*) a lack of material accounting procedures to detect and localize nuclear losses; (*f*) inadequate measurements of waste and scrap nuclear materials during reprocessing, manufacture and transport; and (*g*) antiquated tamper-indicating seals and tags that fail to provide timely detection.

The study recommended long-term indigenization of MPC&A activities and stressed the importance of nurturing Russian ownership of the technical solutions resulting from the Russian–US programmes.[81] While the DOE has made substantial headway in implementation, administrative problems in Russia have impeded progress. In some cases US specialists have been denied routine access, there has been confusion as to Russian certification requirements for MPC&A equipment, or there has been indecision on the part of Russia. The study concluded that neither Russia nor the USA has developed a long-term strategy to ensure the sustainability of MPC&A systems. Storage areas must be further consolidated, transportation programmes need to be expanded, and additional US funds should be made available for the indigenization of Russian MPC&A equipment. In the related area of technology exports, the USA is sponsoring training programmes in the USA for officials of Russia and the newly independent states in order to strengthen controls.[82]

Programmes to assist weapon scientists

Former Soviet nuclear weapon scientists are faced with the stark choices of unemployment, work in a non-nuclear government job, emigration to another country or conversion of their skills for work in the civilian sector.[83] The 1994 Initiatives for Proliferation Prevention (IPP) programme is a cooperative Minatom–DOE programme to assist scientists with nuclear weapon expertise to apply their skills to development and product manufacturing in the commercial sector. The NNSA has claimed that the programme has provided alternative, peaceful employment to roughly 8000 former Soviet specialists on weapons of mass destruction. Another programme is the 1998 Nuclear Cities Initiative (NCI), which is directed at improving the commercial sector in Russia's 10 formerly secret and still closed nuclear cities. The NNSA states that '30 civilian projects [were] funded through NCI, potentially employing more

[81] US Department of Energy (DOE), *MPC&A Program Strategic Plan* (DOE: Washington, DC, Jan. 1998).

[82] Bertsch, G. and Potter, W. (eds), *Dangerous Weapons, Desperate States* (Routledge: London, 1999).

[83] Schweitzer (note 39).

than 700 people'. The goal is to assist in planning and with loans to establish new industries. International development centres and open computing centres have been established in Sarov, Snezhinsk and Zheleznogorsk, but US funding may be limited in the future.[84] Congress combined the IPP and NCI programmes in November 2001.[85] A broader approach reaches out to the US commercial sector directly through the US Industry Coalition, an association of US companies and universities. As of December 1998 the IPP programmes had funded over 400 projects in Belarus, Kazakhstan, Russia and Ukraine. The US Industry Coalition has brought together the newly independent states and US commercial entities to collaborate on projects involving about $164 million.[86]

The International Science and Technology Centre in Moscow and the Science and Technology Centre in Ukraine have been established to provide former Soviet nuclear weapon scientists with opportunities in non-military research.[87] The US Department of State manages the science and technology centres, which have funded 840 non-military scientific projects and engaged over 30 000 scientists between 1994 and 2000. These programmes have experienced some start-up problems, but they have helped former weapon scientists as Russia downsizes its complex.

Warhead monitoring

START III

The Joint Statement issued at the conclusion of the March 1997 Helsinki summit meeting called for a START III agreement that included 'measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads . . . to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads'.[88] Presidents Clinton and Yeltsin also agreed to 'explore, as separate issues, possible measures relating to . . . tactical nuclear systems, to include appropriate confidence-building and transparency measures', and to 'consider the issues related to transparency in nuclear materials'.

The statement linked the US concern about Russian tactical weapons with the Russian concern about a potential US breakout from the START treaties. However, the statement could be interpreted in a another way. For example, meas-

[84] Desmond (note 39).

[85] US General Accounting Office (note 33); and Bleek, P. C.., 'DOE threat reduction funding cut, programs reorganized', *Arms Control Today,* vol. 31, no. 8 (Dec. 2001), p. 23.

[86] Bell, D. *et al*., 'Progress in nonproliferation: Initiatives for Proliferation Prevention, the US Industry Coalition, and other international programs', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

[87] US General Accounting Office (GAO), *Weapons of Mass Destruction*: *State Department Oversight of Science Centers Program*, GAO-01-582 (GAO: Washington, DC, 2001).

[88] Joint Statement on Parameters on Future Reductions in Nuclear Forces, The White House, Office of the Press Secretary, Washington, DC, 21 Mar. 1997, available on the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/resources/summits6.htm#parameters>.

ures relating to the destruction of warheads might be interpreted to apply only to those warheads that are to be removed under a START III accord or only to those warheads declared excess to military needs. Although it is important to dismantle warheads removed from delivery vehicles that are scheduled for elimination, this is not sufficient. Little would be gained by verifying the dismantlement of certain warheads if other warheads in the stockpile could take their place or if new warheads could be produced to replace them. Warheads can be interchangeable if the delivery systems are modified.[89] To improve security benefits, transparency measures must be comprehensive. With the exception of the monitoring provisions specified in the INF and START treaties, as described above, warheads remain outside the bounds of any transparency or verification measures. In the years to come, this will be the greatest challenge in the development of a comprehensive regime to control warheads and fissile materials.

Joint technical work

The degree to which warheads are not subjected to any controls or transparency measures is offset somewhat by the degree to which the DOE laboratory-to-laboratory programme made significant progress in engaging Russian and US scientists in exploring the challenges of warhead monitoring.[90] The 2000 Warhead Safety and Security Exchange Agreement was extended in 2001 for five years to continue exchanges of unclassified warhead data, to enhance the safety and security of nuclear weapons, and to continue the laboratory-to-laboratory contracts which support research in this area. There has been considerable progress on this work, as described in appendix 8A, but more advances could have been made with greater political cooperation at the highest levels of both governments.

V. Conclusions

The negotiations on and initiatives for reducing cold war nuclear arsenals and for strengthening transparency have led to the establishment of cooperative programmes and measures that would have been inconceivable a decade earlier. In the area of enhancing controls over fissile materials and establishing mutual monitoring rights, the progress has been without precedent. Security at Russian nuclear facilities is being enhanced through the MPC&A programme, and

[89] E.g., US Minuteman ICBMs carry the W87 warhead developed for the MX missile, but they could also be armed with the W62 or W78 warhead developed for the Minuteman, large numbers of which are maintained in storage. The Trident II SLBM can carry either the W76 or the W88 warhead, or both; large numbers of W76 warheads are maintained in storage. With modifications, the Minuteman could carry the SLBM warheads and the Trident II could carry the ICBM warheads. Different types of weapons often share the same nuclear components, so 1 type could be used as the basis for another, just as the USA used W85 warheads from eliminated Pershing II missiles to build new B61 bombs. Russia reportedly has an even greater degree of interchangeability within its warhead stockpile.

[90] Bieniawski and Irwin (note 37).

excess fissile materials are being constrained with the construction of the Mayak storage facility and the HEU Agreement. However, much more work remains to be done. This section summarizes the lessons of the past decade.

The Russian Advisory Task Force appointed by US Secretary of Energy Bill Richardson argued for considerably increased funding and stronger directions in a report in 2001. The findings of the panel, chaired by former Senator Howard Baker and former Presidential Counsellor Lloyd Cutler, should be closely examined because of the high calibre of its membership and its bipartisan nature.[91]

1. The most urgent national security threat to the United States is the danger that weapons of mass destruction, or weapon-usable material in Russia, could be stolen and sold to terrorists or hostile states and used against US troops abroad or citizens at home.
2. The current non-proliferation programmes of the DOE, the DOD and related agencies have achieved impressive results, but their limited mandate and funding fall short of what is required to adequately address the threat.
3. The president and congress face the urgent national security challenge of devising an enhanced response proportionate to the threat.

The panel declared that Russia and the USA should agree at high levels of government on the degree of transparency needed to ensure that US-funded activities will have measurable impacts. It recommended $30 billion in additional funding over the next decade, which would be 1 per cent of the projected US defence budget for this period.

Lessons

The past decade began with a high degree of cooperation between Russia and the USA on enhancing physical security, improving fissile material accounting, developing new monitoring approaches and providing for the irreversible disposition of excess nuclear warheads and materials. Over the past few years, however, progress has waned as competing pressures in each state have caused delays. These problems must be resolved if progress is to be renewed.

Access rights and reciprocity

The lack of access to critical facilities in both states has adversely affected the ability to win consensus on monitoring regimes. US officials have made many more visits to Russia than Russian officials have to the USA since Russia has more excess material, some of which is not adequately guarded, and more

[91] Baker, H. and Cutler, L. (Co-Chairs, Russian Task Force, Secretary of Energy Advisory Board), *A Report Card on the Department of Energy's Nonproliferation Programs with Russia* (US Department of Energy: Washington, DC, 10 Jan. 2001), pp. 2–3, available at URL <http://www.ceip.org/files/projects/npp/pdf/doetaskforceappendices.pdf>.

MPC&A measures are needed. The USA is asking for and feels entitled to access rights because it is purchasing Russian HEU and funding the Mayak storage complex. For the overall benefit of their cooperation, it is clear that the USA should ensure the development of as much symmetry as possible between the two sides.

Degree of monitoring

The level of monitoring can rise with increased experience and trust, as in the case of monitoring under the HEU Agreement.

Secrecy

The former Soviet Union was often obsessed with secrecy, but the USA also exhibits this tendency. Segments of the US Government are negative towards the constraints of mutual monitoring. The recent concerns about the loss of secret information from Los Alamos sparked the creation of the National Nuclear Security Administration and the introduction of lie-detector tests at the national laboratories, which has affected staff morale. While there are legitimate reasons for keeping national security information secret, relatively harmless facts are also kept secret, which can impede Russian–US progress in reducing the nuclear threat. The USA favours 'transparency measures' in general, but in Russia there is a fear that they would allow the stronger party to spy on the weaker one. The USA has learned a great deal about the Russian nuclear complex. Although this knowledge may not be of great assistance to the US military, it is often hard to convince Russian officials of this.

Entanglement with other issues

Cooperation and progress have been slowed by other, unrelated issues, such as the US involvement in the wars in Bosnia and Herzegovina and Kosovo, the enlargement of NATO, the abandonment of the ABM Treaty and the planned deployment of missile defences. To the extent that these issues adversely affect Russian–US relations, they make the task of improving controls over nuclear weapons and materials harder to achieve.

Diplomatic strategy

The eagerness of the USA to move forward on a large and complex agenda may in 1995 have frightened Russia into pulling out of the negotiations on the Agreement for Cooperation and taking a more hesitant position concerning transparency and irreversibility. The USA has more personnel available to conduct negotiations, thus causing Russia to suffer from 'negotiation fatigue'. This may be one of the reasons why Russia prefers a slow, 'step-by-step' approach. Ultimately, both states will act only when they view a particular arrangement as beneficial to their national security.

Incentives

The financial assistance which the USA provided to Russia in exchange for monitoring rights has created an incentive that has sometimes helped move the agenda forward. Unless Russia and the USA return to their former level of cooperation, the availability of funds will be a less effective incentive in the future. Once the USA has completed its purchase of the Russian HEU, paid for the Mayak facility and helped with MPC&A, it is less clear what type of financial arrangements can promote mutual monitoring. National pride, the fear of revealing secret information and the rising price of Russian oil all contribute to reducing the incentives Russia has had from financial aid. Funding alone will not be enough to determine the best approach to devising the best arrangements, and there are reasons to believe that this approach should be gradual, with a negotiation strategy based on unilateral measures and executive agreements.

Leadership

Between 1994 and 1997, presidents Clinton and Yeltsin agreed on four occasions to broad measures for the enhancement of transparency, irreversibility and safeguards on excess nuclear warheads and materials. One agreement was to exchange stockpile data, but thus far only the USA has responded and only with data on its plutonium stockpile. In general, while technology experts in both states agree on the usefulness and value of the monitoring technologies, this does not always translate into policy. There is concern that support for these programmes may diminish unless there is a commitment from leaders at the highest level.[92] The Bush Administration's withdrawal from the ABM Treaty, its rejection of the stronger verification measures of the proposed START III accord and the downgrading of some cooperative programmes with Russia, taken together, is not a hopeful sign.

An integrated approach

The programmes outlined in this chapter are complex and difficult to analyse. US Government proposals and budget requests have often seemed to be overly detailed and lacking in coherence. Acceptance of these programmes overall has been negatively affected by such complexities. It is obvious that a more integrated approach is necessary. One attempt in this direction has been made by Siegfried Hecker, former Director of the Los Alamos National Laboratory, who has called for an integrated strategy of nuclear cooperation with Russia.[93] It is to be hoped that more proposals for strategies of this type will be made and will gain momentum in the near future.

[92] Luongo (note 38).

[93] Hecker, S., 'Thoughts about an integrated strategy for nuclear cooperation with Russia', *Nonproliferation Review*, vol. 8, no. 2 (summer 2001), pp. 1–24. Hecker developed an integrated approach for 33 issues, under 6 generic topics, for 3 situations. In the first, Russia is an ally of the USA, in the second Russia's status remains unchanged, and in the third Russia re-emerges as an adversary.

6. Nuclear transparency from the perspective of the non-nuclear weapon states

Gunnar Arbman

I. Introduction

There are eight nuclear weapon states (NWS) and 183 non-nuclear weapon states (NNWS). Most of the transparency issues discussed in this chapter are relevant only for the five nuclear weapon states parties to the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT)—China, France, Russia, the United Kingdom and the United States. The term NWS therefore applies mainly to these five states. The three de facto NWS—India, Israel and Pakistan—are noted as such in this chapter.

The nuclear weapon-related considerations and decisions of the NWS obviously affect the security of the NNWS. This dependence is often more profound than other national security issues. Nevertheless, nuclear weapon-related deliberations in the NWS and the de facto NWS today seem to be of little interest to the NNWS—at least compared to the situation during the cold war era, and possibly as a consequence of the end of the cold war. Transparency in nuclear warheads and materials is no exception to this rule.

At first glance, it would seem that the NNWS, so heterogeneous with regard to such factors as population, land area, location and level of economic development, are simply too dissimilar to be considered as a group except in the context of their non-possession of nuclear weapons. However, in many respects, the non-possession of nuclear weapons gives them a similar perspective on many nuclear weapon issues, including transparency. While some of the conclusions presented in this chapter might not be valid or relevant for all the NNWS, the chapter focuses on areas where their general interests diverge from those of the NWS and the de facto NWS and points out issues on which interests coincide.

International debates and publications on nuclear weapon issues usually represent opinions in the NWS. This is not surprising, given the important role the NWS assign to nuclear weapons. Moreover, the tendency for the NWS to decide the agenda is facilitated by the fact that knowledge of sensitive technical and operational issues within the NWS, for security reasons and because of their obligations under the NPT, is not available to the NNWS. Whatever the reasons, nuclear weapon debates often tend to focus on issues that are more relevant to the NWS than to the NNWS. In particular, this is the case for those

NNWS parties to the NPT with only negative security assurances (NSA)[1] from the NWS, but no 'strong' positive security assurances (PSA)[2] because they are not key allies of one or more NWS. It is something of an irony that, while NNWS with only NSA constitute by far the majority of the NNWS, their contribution to international debates on nuclear weapon-related issues is the least conspicuous.

In the light of the somewhat precarious world situation with regard to nuclear weapons, it is remarkable that almost all the NNWS are in full compliance with their safeguards agreements with the International Atomic Energy Agency (IAEA). There are exceptions to this rule, Iraq being the most prominent, but it is striking that the NPT has been so successful in preventing horizontal proliferation and rendering almost all the NNWS completely transparent with regard to the absence of nuclear weapons or nuclear weapon programmes. While transparency in the NWS may not noticeably enhance the security of the NNWS, it is still significant as a gesture of reassurance, indicating a willingness on the part of the NWS to join the NNWS in nuclear transparency arrangements. Transparency has a role as a confidence-building measure (CBM) but its role for the NWS as a prerequisite for further progress in verified arms control and disarmament is more important.

Finally, transparency in nuclear safety and custodial security is likely to enhance the ability of the NNWS to combat the illicit traffic in nuclear material, principally weapon-usable fissile material, and thereby their efficiency in impeding horizontal proliferation to states or sub-state terrorist groups.

[1] China, France, Russia, the UK and the USA have all granted non-legally binding NSA to NNWS parties to the NPT in UN Security Council Resolution 984, 11 Apr. 1995, URL <http://cnsdl.miis.edu/npt/npt_4/unsc984.htm>. The resolution has been further reinforced by unilateral declarations of doctrine. In the case of the UK: 'Britain has repeatedly made it clear that we will not use nuclear weapons against a non-nuclear weapon state not in material breach of its nuclear non-proliferation obligations, unless it attacks us, our Allies or a state to which we have a security commitment, in association or alliance with a nuclear weapon state'. British Ministry of Defence, *Strategic Defence Review,* July 1998, available at URL <http://www.mod.uk/issues/sdr/arms_control.htm>. Russia and the USA explicitly exclude a NNWS from their NSA if it resorts to massive use of other weapons of mass destruction such as biological weapons and/or chemical weapons against them or their armed forces. There are indications that France and the UK have taken the same position since their declarations of 1995. Finally, NNWS allies of one or more NWS are not granted NSA by other, potential adversary, NWS. China extends an unconditional NSA to NNWS and has declared a no-first-use nuclear weapon policy, implying that it will not use nuclear weapons against a state that does not use nuclear weapons first against China. 'China's national statement on security assurances, 5 April 1995', URL <http://www.nti.org/db/china/engdocs/npt0495a.htm>. Although the 113 states parties to nuclear weapon-free zone treaties have legally binding NSA from NWS, they are not treated as a special case in this chapter.

[2] 'Strong' positive security assurances are extended by the USA to key NNWS allies and friends. See Cohen, W. (US Secretary of Defense), *Annual Report to the President and the Congress* (Department of Defense: Washington, DC, 2000), URL <http://www.defenselink.mil/execsec/adr2000/index.html>. A common interpretation is that these states are under the 'nuclear umbrella' of the USA. In the Russian military doctrine adopted on 21 Apr. 2000, 'strong' PSA are given to Russia's NNWS allies: 'The Russian Federation reserves the right to use nuclear weapons in response to the use of nuclear and other types of weapons of mass destruction against it and (or) its allies'. 'Russia's military doctrine', *Arms Control Today*, vol. 30, no. 4 (May 2000), p. 31. Through NATO, the UK extends PSA to its non-nuclear NATO allies in close cooperation with the USA. Although there have been tendencies in the 1990s to extend the nuclear umbrella to those European NNWS which are NATO allies, the present French position on PSA is not entirely clear. Altogether, this means that at least NATO members, friends and allies as well as allies of Russia have 'strong' PSA. India and Pakistan have not extended PSA to any state.

II. Transparency related to the Non-Proliferation Treaty

The main instruments for the NNWS to exert at least some influence on nuclear weapon transparency are Article VI of the NPT[3] and the Final Document of the 2000 NPT Review Conference.[4] Their actual options are limited, however.

In the Final Document of the 2000 NPT Review Conference, transparency is explicitly mentioned, for the first time ever in an internationally agreed document. In Article VI (15), 'The Conference agrees on . . . practical steps for the systematic and progressive efforts to implement Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons and paragraphs 3 and 4(c) of the 1995 Decision on "Principles and Objectives for Nuclear Non-Proliferation and Disarmament"'.[5] It specifies the need for the NWS to work towards nuclear disarmament in a way that 'promotes international stability, and [is] based on the principle of undiminished security for all', and calls for '[i]ncreased transparency by the nuclear-weapon States with regard to the nuclear weapon capabilities and the implementation of agreements pursuant to Article VI and as a voluntary confidence-building measure to support further progress on nuclear disarmament'.[6]

So far, the NNWS have not been very active in pursuing efforts to increase nuclear weapon transparency, for reasons which are not entirely clear. Their seemingly passive position might, in part, be attributable to the legacy of the cold war period, when the two military blocs—NATO and the Warsaw Treaty Organization—were so large and powerful that they by and large precluded the NNWS, except a few non-nuclear weapon NATO states, from having any influence on the nuclear weapon policies and decisions of the NWS. The conclusion of the NPT in this period was more the result of coinciding non-proliferation interests among the NWS than of efforts of the NNWS. Another reason might be the realization that transparency in nuclear weapon issues is not a simple matter since it may conflict with the national security interests of the NWS as well as with Article I of the NPT.[7] Finally, the current lack of interest in nuclear weapon transparency may be related to the general lack of interest in nuclear

[3] The NPT was opened for signature in 1968 and entered into force in Mar. 1970. The complete text and comments on the treaty are available at URL <http://www.state.gov/www/global/arms/treaties/npt1.html>. In Article VI of the treaty, 'Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control'.

[4] Final Document of the 2000 Review Conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2000/28, 24 May 2000, available at URL <http://www.iaea.org/worldatom/Press/Events/Npt/npt-2000.shtml>.

[5] Final Document (note 4), para. 15, p. 30.

[6] Final Document (note 4), para. 15, step 9, p. 31.

[7] Article I contains the central non-proliferation statement of the NPT: 'Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices'.

arms control and disarmament that seems to prevail in many NNWS, notwithstanding the progress made at the 2000 NPT Review Conference.

It is important to note that the continued remarkable success of the NPT should not be taken for granted. It is an open question whether the multipolar relationship between the NWS is more conducive to non-proliferation than the predominantly bipolar cold war structure was. For parts of Asia and the Middle East, this is in all likelihood not the case. Furthermore, key technological barriers—in the form of secret scientific and engineering know-how for the production of weapon-grade fissile material as well as the design and construction of unsophisticated fission-type nuclear weapons—are gradually being lowered, if not removed completely.

Article X of the NPT offers legal means for NNWS to withdraw from the treaty.[8] Hence, only one factor prevents the NNWS capable of producing a small nuclear arsenal from doing so—their political will to remain in compliance with the NPT.

III. Transparency measures relevant to the NNWS

The interests of the NNWS coincide with those of the NWS on some, but not all, aspects of transparency. For example, there is widespread agreement between the NNWS and some of the NWS that increased transparency is a CBM. The positive effect of confidence building is not limited to relations between the NWS but also extends to relations between them and the NNWS. In addition, many NNWS, at least within influential circles, tend to regard transparency as a step towards nuclear abolition rather than merely one towards further progress in disarmament and arms control.

An important underlying rationale for the support of the NNWS for the abolition of nuclear weapons is the 'security gap'—the security deficiency experienced by the NNWS vis-à-vis the NWS and the de facto NWS. While for obvious reasons this is rarely mentioned, most NWS and de facto NWS can, if they choose to do so, threaten the vital national interests of at least neighbouring NNWS. This situation will not change unless the NNWS acquire a minimal nuclear deterrent and become NWS or obtain 'strong' PSA from a NWS. For some NNWS, mainly those outside the nuclear weapon-free zones, this is a dilemma which is often handled by more or less ignoring the issue in national security considerations. Although outside the scope of this chapter, it may be mentioned that this security gap often compels the USA to extend strong PSA to NNWS, with a potential concomitant risk that US assets might be at risk due to some regional conflict involving such a NNWS. The current US missile defence plans are directed *inter alia* to reducing or eliminating such risks. The

[8] 'Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests.'

very existence of this security gap creates a situation that is intrinsically unstable.

A long-term solution to this security deficiency is nuclear abolition. However, policy makers in the NWS, except possibly those in the UK, appear to subordinate this goal to progress in arms control and disarmament.[9] Moreover, progress in disarmament is inhibited by the concerns of the NWS that a reduction in the number of nuclear weapons beyond a certain minimum will lead to a decrease in nuclear stability. Hence, there are genuine differences of interest between the NNWS and the NWS, not only with regard to nuclear abolition but also on the actual pace of nuclear disarmament.

In addition, the importance of some national security considerations within the NWS and the de facto NWS might not be fully realized or even acknowledged by the NNWS. Differences here would necessarily lead to differences on transparency as well.

Nuclear disarmament

While transparency alone will not result in nuclear disarmament, verification of nuclear disarmament can hardly be achieved without transparency. Furthermore, a lack of well-designed and -implemented verification procedures in the disarmament process is bound to have a detrimental effect on confidence in nuclear disarmament efforts worldwide.

Nuclear disarmament can take place in many arenas. In warhead dismantlement, the NNWS would be interested in verifiable information on whether the weapon-grade fissile material extracted in the dismantlement process is to be stored as weapon-usable pits or converted into solid pieces. In order for the NNWS to be assured that dismantlement is taking place as asserted by the NWS, greater transparency in the warhead dismantlement process is needed. It goes without saying that such transparency measures must be sufficiently non-intrusive to be acceptable to the NWS and they must be acceptable in the context of the NPT.

As a confidence-strengthening signal to the NNWS, verification of nuclear warhead dismantlement should be carried out by an independent international organization rather than by the disarming parties, as in verification of the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty) and the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty). As shown in other chapters of this volume, technical procedures for the authentication of nuclear warheads, without revealing their exact nature, are being actively investigated today. This could *inter alia* pave the way for a future regime for international verification of the dismantlement process without violating Article I of the NPT. However, it is important not to allow transparency to interfere with disarmament measures.

[9] British Ministry of Defence (note 1), point 20: 'The challenge is to create the conditions in which no state judges that it needs nuclear weapons to guarantee its security'.

There is another, less tangible link between transparency and nuclear disarmament. A genuine commitment to greater transparency in nuclear warheads and material stockpiles would be perceived by many NNWS as a sign of the NWS' willingness to proceed with mutual nuclear disarmament efforts. Since this would diminish the long-term instability associated with the security gap between the NWS and the NNWS, it would also enhance mutual security.

Discontinuation of the production of weapon-grade fissile material

While increased transparency in nuclear warheads would be a CBM as well as a vital step towards disarmament verification and improved mutual security, transparency in fissile material is at least as important. Without transparency in fissile material, wherever it is located in the NWS, it is difficult to see how stocks could be declared, and this has constituted a serious obstacle to the talks on a Fissile Materials Cut-off Treaty (FMCT). Hence, transparency with regard to weapon-grade fissile material both in nuclear warheads and outside them is likely to be at least a long-term prerequisite for an FMCT. In addition, transparency in all past production of weapon-grade fissile material seems to be indispensable for an effective FMCT verification regime, even though past production will pose accounting problems (i.e., the need for 'nuclear archaeology' verification techniques).[10]

Nuclear safety and custodial security

From the perspective of most NNWS, there is an obvious need for enhanced transparency in the safety and security arrangements at nuclear weapon storage sites, during weapon transportation and so on. Transparency measures in this realm must be designed so as not to inadvertently facilitate such problems as theft, illicit trade and corruption. Nevertheless, identifying transparency measures and verification procedures that can convince the NNWS of the adequacy of nuclear weapon safety and security arrangements in the NWS, without degrading these arrangements or involving unacceptable intrusiveness, is a challenge that needs to be addressed. Russian and US initiatives for increased transparency in security arrangements might be the best path towards the creation of conditions favourable to greater transparency in other NWS.

The NNWS are similarly concerned about the safety and security arrangements for the storage, transportation and, where applicable, production of weapon-grade fissile material in the NWS and de facto NWS. Their reasons are largely the same as those of the NWS: fear of illegal transfer of fissile material to 'states of concern', that is, smaller states in suspected non-compliance with the NPT because of possible clandestine nuclear weapon programmes, or sub-state groups that want to acquire a small arsenal of crude nuclear devices. Greater transparency in the safety and security of weapon-grade fissile material

[10] For further discussion of an FMCT see chapters 5 and 10 in this volume.

would certainly be acknowledged as an important CBM by the NNWS. Again, verification procedures would need to be designed in a way that is acceptable to the NWS and does not facilitate the proliferation of stockpiled material—yet another challenge to be addressed. The same arguments made for achieving greater transparency in nuclear weapon security arrangements are also likely to hold in this case—that the other NWS and the de facto NWS would follow suit if Russia and the USA were to make the first move on a bilateral basis. The IAEA or another international organization could eventually have an important role to play in this regard.

Non-strategic nuclear weapons

Most NNWS are more concerned about the non-strategic, or tactical, nuclear weapons of the NWS than about their strategic weapons. Non-strategic weapons are more likely to be targeted at the NNWS in a nuclear conflict. Because most nuclear weapon delivery vehicles are dual-capable—capable of delivering both nuclear and conventional weapons—a shortage of delivery systems is generally not the same limiting factor for non-strategic nuclear weapons as it is for strategic weapons. Non-strategic nuclear weapons are usually considered more likely to be diverted or sold illegally and are easier to operate than strategic weapons because of their low weight, small size, less stringent physical security arrangements and, at least for some of the older types and even some newly designed weapons, less complicated locks and procedures to prevent unauthorized detonations. The NNWS do not know how many unsafe non-strategic nuclear weapons are held by the NWS and de facto NWS and hence cannot estimate the probability that a serious accident might occur. Unauthorized launches pose similar dangers. Aside from the direct harmful consequences (e.g., radioactive fallout over the territories of the NNWS), there is at least a theoretical risk that an accidental or unauthorized explosion by a NWS could be interpreted as an initiation of hostilities by an adversary NWS or a de facto NWS and trigger a nuclear response that could eventually affect the NNWS.

Hence, as a security-enhancing measure, transparency in tactical nuclear weapons is considerably more important for most NNWS than further transparency measures concerning strategic nuclear weapons such as those accountable under the START I Treaty.

Periodic declarations by the NWS of the numbers and types of all their operational and reserve nuclear weapons would be an important transparency measure. Such declarations should include retired nuclear weapons as well as new nuclear weapons deployed during the period. The yields of the various types of nuclear weapon would also be of significant interest, as would the ranges of their designated delivery vehicles. Because of the high mobility of some of these weapons and the vulnerability to which the NWS would be exposed if storage sites were to become known, such sites would not necessarily have to be disclosed. Independent and reliable verification by an international body such as the IAEA would be necessary for maintaining confidence in a future transparency regime, even if it might encounter practical difficulties. Similar difficulties have not been insurmountable in the cases of the 1996 Comprehensive Nuclear Test-Ban Treaty (CTBT) and the 1993 Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention, CWC), where special international verification organizations have been established. In this context, it is also encouraging to note the recent progress in the development of techniques for the authentication of nuclear warheads without revealing their exact nature.[11] Again, a Russian–US agreement on enhanced transparency along these lines might be the most important incentive for more comprehensive transparency agreements between other NWS and later the de facto NWS.

The national security of nuclear weapon states

Those NWS that refer to their nuclear weapons in national security doctrines commonly describe possession as an important element of their national security. The main role of their nuclear weapons is to deter a potential adversary—usually, but not always, another NWS—from aggression. Since nuclear deterrence is intimately linked to the concept of a 'nuclear threshold' and the precise level of this threshold must remain unknown in order not to diminish the deterrence effect, maintaining deterrence is inherently in conflict with many aspects of transparency.

According to current nuclear doctrines, 'vital national interests' must be threatened for the NWS (and presumably also the de facto NWS) to use or threaten to use nuclear weapons. The main purpose of nuclear deterrence would be to prevent or de-escalate a major conflict. This section discusses the declarations of the vital national interests of the NWS, leaving aside the interests of the three de facto NWS for reasons of space.

The USA's vital national interests are those of 'broad, overriding importance to the survival, security, and vitality of the United States', including: (*a*) the physical security of US territory and that of US allies and friends; (*b*) the safety of US citizens at home and abroad; (*c*) the economic well-being of US society; and (*d*) the protection of critical US infrastructure—including energy, banking and finance, telecommunications, transportation, water systems, and government and emergency services—from disruption intended to cripple its operation.[12] More extensive discussions of contingencies in which there could be a

[11] See the chapters in Part II of this volume, especially chapter 8 and appendix 8A.

[12] US Department of Defense (DOD), *Annual Report to the President and the Congress* (DOD: Washington, DC, 2001), Part I, chapter 1, pp. 4–5, URL <http://www.defenselink.mil/execsec/adr2001/index.html>.

need for US nuclear deterrence have been published by the National Institute for Public Policy[13] and in the 2002 US Nuclear Posture Review.[14]

The Russian national security doctrine uses the phrase 'critical to the national security of the Russian Federation'.[15] Nuclear deterrence is linked to vital Russian interests at stake in a global war or a major regional war. Concerning regional conflicts, the doctrine cites conflicts 'waged with the involvement of two or several states . . . utilizing both conventional and nuclear weapons'.[16] The doctrine emphasizes escalation risks, that is, the risk that a local war may turn into a major regional war that would threaten Russia's vital national interests. The use of nuclear weapons as a demonstration is believed to have a de-escalating effect on an armed conflict. Generally speaking, Russia's stated vital national interests seem to have a stronger link to purely military threats than do those of the USA.

China has defined its vital national interests rather vaguely. In the policy document *China's National Defence 2000*, 'resisting aggression, curbing armed subversion, and defending state sovereignty, unity, territorial integrity and security' are stated as China's main interests.[17] Furthermore, it declares that, while China upholds a no-first-use nuclear policy, it 'maintains a small but effective nuclear counterattacking force in order to deter possible nuclear attacks by other countries'.[18]

The 1994 French White Paper on Defence outlines two scenarios in which 'nuclear dissuasion' might be considered in order to protect French vital national interests.[19] One involves a major threat against Western Europe. The other scenario is a regional conflict that could affect French vital interests in Europe or, in a longer time frame, in the Mediterranean or in the Near and Middle East.[20] After publication of the White Paper, presidential and government statements made it clear that nuclear deterrence also applies in the event of the threat of the use of biological and chemical weapons if France's vital interests are at stake.

The vital national interests of the UK are not explicitly stated but it is interesting and encouraging to note that the goal of a nuclear weapon-free world is mentioned in the 1998 British Ministry of Defence document.[21]

[13] Payne, K. B. *et al., Rationale and Requirements for US Nuclear Forces and Arms Control, Vol. I, Executive Report* (National Institute for Public Policy: Fairfax, Va., Jan. 2001), available at URL <http://www.nipp.org/publications.php>.

[14] US Department of Defense, 'Nuclear Posture Review', Jan. 2002, URL <http://defenselink.mil/faq/pis/nuclear.html>.

[15] 'Russia's military doctrine' (note 2), p. 31.

[16] 'Russia's military doctrine' (note 2), p. 34.

[17] Chinese Ministry of Defence, *China's National Defence 2000* (Information Office, State Council of the People's Republic of China: Beijing, Nov. 2000), p. 3, available at URL <http://www.nti.org/db/china/engdocs/wpnd2000.htm>.

[18] Chinese Ministry of Defence (note 17), p. 4.

[19] French Ministry of Defence, *Livre Blanc sur la Defénse* [White Paper on Defence] (Army Information and Public Relations Service: Paris, 1994).

[20] These are described in Grand, C., *A French Nuclear Exception?*, Occasional Paper no. 38 (Henry L. Stimson Center: Washington, DC, Jan. 1998); and Tertrais, B., *Nuclear Policies in Europe*, Adelphi Paper 327 (International Institute for Strategic Studies: London, 1999).

[21] British Ministry of Defence (note 1).

It can be concluded from the above that there are only two circumstances in which the NNWS can be seen as posing threats to the vital national interests of the NWS. First, a NNWS might be a part of—or form—an alliance with a NWS. Second, a NNWS could obtain access to large enough stocks of chemical and/or biological weapons to be able to hold the armed forces or the society of a NWS at bay—a lesson clearly drawn from the 1991 Persian Gulf War.

The NWS often point out that transparency could adversely affect their security. They are particularly concerned about the decrease in the deterrence value of their nuclear weapons, the disclosure of possible deficiencies in their nuclear weapon stockpiles and the facilitation of military planning for a potential NWS adversary. However, if all the NWS (and eventually the de facto NWS) agree to implement greater transparency, some 'diminishing of national security' would be shared by all states. Since national security is a relative concept, related *inter alia* to the national security of other (potential adversary) states, the enhanced confidence achieved might well result in enhanced security for all parties.

Arguably, the security concerns of the NWS about the possible detrimental effects of transparency on deterrence and the concomitant preference for secrecy are out of proportion to the genuine security deficit experienced by most NNWS. It would, in fact, seem rational from the point of view of the NWS to focus more on the nuclear weapon proliferation risks within the global security system, which are being exacerbated by *inter alia* the security gap between the NWS and the NNWS. The positive effects of increased transparency in this respect might outweigh the likely negative security implications for the NWS, especially in a medium- to long-term perspective.

From the point of view of the NNWS, it is important to have at least some transparency agreements rather than none at all. Since a maximalist approach is likely to be fruitless, the obvious national security concerns of the NWS would have to be clearly acknowledged by the NNWS. Exactly which transparency measures would be considered unacceptable for the NWS—and the de facto NWS—remains to be seen, but such measures would probably include detailed information on the locations of storage sites and the operational status of their weapons. The exact isotopic and chemical compositions of fissile material in nuclear weapons might be another type of information that should not be revealed because of the NWS' obligations under Article I of the NPT. There are most likely other technical issues that are too sensitive to reveal. Hence, from the point of view of the NNWS, demands should not be made for transparency measures that are too sensitive for the NWS. In addition, future nuclear weapon transparency arrangements must not be in violation of Article I of the NPT.

The international prestige value of nuclear weapons

In the nuclear weapon debate, the argument is sometimes made that transparency will reduce the international prestige value of nuclear weapons,[22] based on a belief that the more secrecy and mystique surrounding nuclear weapons, the higher the prestige value. The argument from the perspective of the NNWS is that the international prestige value of nuclear weapons is already diminishing. Potential nuclear weapon proliferator states, often referred to as 'rogue states' or 'states of concern' because of their suspected non-compliance with the NPT, evoke fear and other negative reactions in the global community. These reactions are even more pronounced with regard to terrorist groups, such as al-Qaeda and Aum Shinrikyo, with an interest in acquiring nuclear weapons. In the long run, it is impossible to maintain a dual standard for the possession of nuclear weapons. The NWS cannot claim that nuclear weapons have a positive international prestige value for the NWS while condemning their acquisition by other states. While the international prestige value of the possession of nuclear weapons is on the decline worldwide, an appreciation for states that could have built a nuclear arsenal but have abstained from doing so (e.g., Japan and Germany) is often expressed. Hence, it is difficult to identify any transparency measures, at least from the point of view of the NNWS, that would have a detrimental effect on the international prestige value of the nuclear weapons of the NWS.

IV. Central transparency issues to be addressed by the NNWS

For several reasons, the most pertinent transparency issues to be addressed are those related to non-strategic nuclear warheads. First, they are at the centre of the discussion of explicit nuclear threats to the NNWS and hence at the core of the destabilizing security gap. Second, official declarations by the NWS provide virtually no transparency in non-strategic warhead holdings, so there is much room for improvement. Third, the fact that the NWS are currently pursuing warhead dismantlement should facilitate their declarations of the numbers and types of dismantled non-strategic warheads. Fourth, influential circles in the nuclear establishments of several NWS appear to want to modernize and expand their existing arsenals of non-strategic nuclear warheads. Finally, the lack of transparency in non-strategic nuclear warheads constitutes a major obstacle to the advancement of arms control and disarmament with regard to weapon-grade fissile material, since it prevents declarations of material inside warheads.

Although only partly linked to the issue of non-strategic nuclear warhead transparency, greater transparency in stocks of weapon-grade fissile material separated from warheads would be significant from the perspective of most NNWS. This is primarily related to concerns about the deadlocked FMCT

[22] British Ministry of Defence (note 1).

negotiations and other arms control efforts. Ultimately, this raises concerns about horizontal proliferation with a subsequent partial or complete collapse of the NPT regime since several NNWS might choose to reduce their security deficiency in relation to the NWS by deciding to acquire a minimal nuclear deterrence. Iran, for instance, might already have decided to do so, and approximately 50 NNWS are believed to possess sufficient technological and financial resources to acquire nuclear weapons.[23]

Greater insight into the safety and security arrangements and procedures for nuclear warheads, fissile material storage sites, transport security arrangements and so on are equally important and of considerable interest to all the NNWS. Such transparency would benefit mutual security and help the NNWS to plan and procure equipment to deal with nuclear proliferation and international nuclear terrorism. The terrorist attacks of 11 September 2001 in the USA indicate that an escalation to this level may not be entirely unthinkable.

V. Options for the NNWS to exert influence towards greater transparency

As a rule, the NNWS have little influence on the nuclear policies of the NWS and the de facto NWS. Probably the most important channel through which they can exert some influence is participation in multilateral arms control and disarmament processes within the framework of the United Nations—in the General Assembly and the Conference on Disarmament. The NPT review conferences offer opportunities every fifth year for discussions of nuclear weapon issues between government representatives from the NNWS and the NWS. There are other forums, such as the IAEA and the Comprehensive Nuclear Test-Ban Treaty Organization, where experts meet informally on a regular basis. NNWS members of the European Union (EU) have additional opportunities to participate in internal EU discussions on nuclear arms control and disarmament issues.

Research institutes, universities and university-affiliated institutes offer possibilities for individuals from the NNWS to participate in their work and to express their views in journal articles, books, conferences and the like at the academic level.[24] The NNWS can also present their views in international and

[23] Personal communication with May, M., Committee on International Security and Arms Control of the US National Academy of Sciences, Director Emeritus, Lawrence Livermore National Laboratory, May 2002.

[24] In the USA, these primarily include the Arms Control Association, the Brookings Institution, the Carnegie Endowment for International Peace, the Center for Nonproliferation Studies (CNS) at the Monterey Institute of International Studies, the Center for Strategic and International Studies (CSIS), the Institute for Science and International Security (ISIS), the Henry L. Stimson Center, the Woodrow Wilson International Center for Scholars and the Council on Foreign Relations. In Western Europe there are, e.g., the International Institute for Strategic Studies (IISS) in London, the Stockholm International Peace Research Institute (SIPRI), the Norwegian Institute of International Affairs (Norsk Utenrikspolitisk Institutt, NUPI) in Oslo, the Danish Institute of International Affairs (Dansk Udenrigspolitisk Institut, DUPI) in Copenhagen, and the Geneva International Peace Research Institute (GIPRI) and the United Nations Institute for Disarmament Research (UNIDIR), in Geneva. The Pugwash Conferences on Science and World Affairs, although a special case, is also in this category.

national non-governmental organizations.[25] Finally, the media—including the Internet—can be used effectively as a channel for generating public opinion and political influence in the NNWS.

VI. Can the Revolution in Military Affairs help to promote nuclear transparency?

To be credible, a proposal for the abolition of nuclear weapons combined with a transparency and verification regime requires alternatives to nuclear weapons that can be used to deter—or if necessary disarm—'states of concern'. Such alternative weapons might well emerge through the increased capabilities of conventional weapons brought about by the Revolution in Military Affairs (RMA). The RMA, which is perhaps more of an information technology evolution than a revolution, has been achieved mainly by and within NATO, in particular by the USA. However, it may be only a matter of time before it enhances worldwide capabilities to combat biological, chemical or nuclear weapons possessed by smaller, less developed nations. It is sometimes implied that there is no alternative to nuclear weapons for destroying such targets as deeply buried installations,[26] underground biological or chemical weapon production plants, or mobile missiles. Nevertheless, the destruction of buried installations with conventional munitions can in principle be achieved by successive 'hits in the same hole' (the 'woodpecker principle'). Chemical and biological production plants hidden in caves or tunnels could probably be destroyed by other means than nuclear explosions, such as fuel air explosives. The destruction of mobile missiles, which is a difficult task because of the available countermeasures, requires detection, identification and precision targeting, which are core features of the RMA. The political costs of using nuclear weapons, especially against a small 'state of concern', are prohibitively high, whereas the political costs of using high-precision weapons are small or perhaps negligible in comparison.

If the RMA eventually provides a conventional capability to deter or prevent states of concern from using non-conventional weapons, it could replace nuclear deterrence. A future multilateral nuclear weapon transparency regime, with all NPT parties as participants, with suitable verification procedures and with well-chosen punitive measures for proven non-compliance, could further suppress the possibilities for states of concern to acquire nuclear weapons since they would run the additional risks of exposure and punishment. The IAEA Strengthened Safeguards System is a recent example of measures that can be taken to improve the probability of detection of non-compliance.[27]

[25] Examples are the British–American Security Information Council (BASIC), the International Physicians for the Prevention of Nuclear War and the Union of Concerned Scientists.

[26] See Payne *et al.* (note 13), pp. 7–8 for a discussion of nuclear and conventional weapon technologies and capabilities.

[27] For a comprehensive account see Häckel, E. and Stein, G. (eds), *Tightening the Reins: Towards a Strengthened International Nuclear Safeguards System* (Springer-Verlag: Berlin, 2000).

VII. Conclusions

The high degree of transparency in the nuclear activities of the NNWS achieved by the application of IAEA international safeguards gives the NWS considerable assurances that nuclear weapon proliferation is not occurring among the NNWS (except perhaps in a few cases).

Similarly, transparency in the NWS is important to the NNWS as a CBM and as a prerequisite for further international arms control and disarmament. Enhanced transparency will have a positive effect not only on cooperation among many NNWS in arms control but also, and more significantly, on their national security by diminishing the security gap that exists between them and the NWS. Furthermore, security decisions and implementation in the NNWS might in turn affect the security of the NWS and the de facto NWS as well—not least within the domain of nuclear proliferation, that is, in maintaining the NPT regime over the long term. Greater consideration should be given to the possibilities opened up by the RMA for more focused and less inhumane conventional weapons as a substitute for nuclear weapons in a counter-force role.

Increased transparency in the safety and security procedures of the NWS and the de facto NWS with regard to nuclear warheads and weapon-usable material would probably help the NNWS to be more efficient in combating nuclear proliferation and the threat of international nuclear terrorism, which has become more important in view of the continued escalation of terrorist acts. The attacks of 11 September 2001 indicate that few, if any, steps remain on the escalation ladder below the use of biological, chemical or nuclear weapons.

It is appropriate to conclude by quoting a statement of the British Ministry of Defence: 'All our forces have an important deterrent role but nuclear deterrence raises particularly difficult issues because of the nature of nuclear war. The Government wishes to see a safer world in which there is no place for nuclear weapons'.[28] From the perspective of the NNWS, greater transparency in issues such as those discussed in this chapter would be an integral part of endeavours in this direction.

[28] British Ministry of Defence, *Strategic Defence Review,* July 1998, Chapter 4: Deterrence and disarmament, point 60, URL <http://www.mod.uk/issues/sdr/deterrence.htm>.

Part II

The technical dimension

7. Stockpile declarations

Steve Fetter

I. Introduction

Information exchanges are at the heart of cooperative efforts to improve national security. In situations in which a lack of accurate information about the military postures of other states could lead to unnecessary expenditures, competition and even conflict, information exchanges or declarations could build confidence by increasing transparency and mutual understanding and communicating peaceful intentions.[1] Such declarations may be informal and unilateral with the expectation that other states will reciprocate or there may be an agreement to report specific information at regular intervals. Examples of the former include the publication of military plutonium inventories by the United Kingdom and the United States;[2] an example of the latter is the United Nations Register of Conventional Arms.[3] Declarations for the sole purpose of increasing transparency are usually not accompanied by formal verification and inspection procedures, but a variety of other measures—site visits, personnel exchanges, and so on—can improve confidence in the correctness of declarations beyond that provided by national intelligence.

Declarations may also be an integral part of a treaty to limit or prohibit certain items. In this case, an initial declaration of the number and location of all treaty-limited items (TLI) is required to establish a baseline from which reductions would proceed. Information may also be exchanged on the location of facilities where these items have been produced or stored in the past. The treaty would specify exactly what information is to be exchanged and the inspection

[1] Müller, H., *The Nuclear Weapons Register: A Good Idea Whose Time Has Come*, PRIF Reports no. 51 (Peace Research Institute Frankfurt (PRIF): Frankfurt, 1998), pp. 5–7. Non-aggressive states may, however, believe that their interests are best served by keeping their military posture ambiguous or secret and that transparency would decrease their security. This is often the case when a state's forces are much smaller than those of potential adversaries or when revealing certain military capabilities might be destabilizing—e.g., France and the UK during the cold war or China and Israel today. Transparency is most appropriate when states are reasonably comfortable with the status quo or when they wish to cooperate in moving towards a new, more stable status quo.

[2] British Ministry of Defence, 'Plutonium and Aldermaston: an historical account', Apr. 2000, URL <http://www.mod.uk/publications/nuclear_weapons/aldermaston.htm>; US Department of Energy (DOE), *Plutonium: The First 50 Years*: *United States Plutonium Production*, *Acquisition, and Utilization from 1944 through 1994*, DOE/DP-0137 (DOE: Washington, DC, Feb. 1996), available at URL <http://www.osti.gov/osti/opennet/document/pu50yrs/pu50y.html>; and US Department of Energy, 'Openness press conference: fact sheets', 27 June 1994, URL <http://www.etde.org/html/osti/opennet/document/press/pcconten.html>.

[3] The UN Register was established by General Assembly Resolution 46/36 L, 9 Dec. 1991, available at URL <http://projects.sipri.se/expcon/res4636l.htm>. The register was put into operation on 1 Jan. 1993, and in Apr. 1993 UN member states began voluntarily submitting data to the UN.

procedures that would be used to verify the accuracy and completeness of the declarations. Most arms control agreements include provisions for initial and subsequent declarations of TLI; examples include the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty), the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty), the 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms (START II Treaty, not in force),[4] the 1993 Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention, CWC) and the safeguards agreements required for non-nuclear weapon states (NNWS) under the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT).

With a few exceptions, nuclear warheads and nuclear materials reserved for military purposes have not been subject to declarations. The Russian–US nuclear arms control treaties focus mainly on limiting or eliminating nuclear delivery vehicles and their launchers; they do not impose direct controls on nuclear warheads. The focus on delivery vehicles and launchers is understandable because they are much easier to count and far more difficult to hide than warheads or materials. They are also militarily more important than warheads because they cost much more to produce and maintain and because a state's capacity to deliver warheads over long distances is much more strategically significant than the sheer size of its warhead or material stockpiles.

That said, increased transparency in nuclear warhead and nuclear material stockpiles is important for several reasons. First, although Russia and the USA agreed in the START I and START II treaties to limit the number of deployed strategic warheads, there is no limit on the number of non-deployed or reserve warheads. One side might therefore worry that the other could rapidly break out of a treaty by deploying reserve warheads on existing missiles or bombers, including conventional aircraft and cruise missiles. Second, there is concern about the number and disposition of non-strategic (or tactical) nuclear weapons. Although Soviet President Mikhail Gorbachev and US President George Bush announced in 1991 that certain Soviet and US non-strategic warheads would be withdrawn and dismantled, an initiative which was continued between Russian President Boris Yeltsin and President Bush in 1992, the resulting declarations of the 1991–92 Presidential Nuclear Initiatives (PNIs) were not legally binding and were not accompanied by verification or transparency measures.[5] Third, there is concern about the safety and security of warhead and material stockpiles, particularly those in Russia. Finally, there is increasing recognition that the long-term stability of the non-proliferation regime depends on continued reductions in nuclear forces and a commitment to the eventual prohibition of

[4] On 14 June 2002, as a response to the expiration of the ABM Treaty on 13 June, Russia declared that it will no longer be bound by the START II Treaty.

[5] See, e.g., Fieldhouse, R., 'Nuclear weapon developments and unilateral reduction initiatives', *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), pp. 67–84; excerpts from the PNIs are reproduced in appendix 2A, pp. 85–92.

nuclear weapons. A declaration of nuclear warhead and material stockpiles could help to address all these issues and would provide a necessary basis for agreements that verifiably limit them.

II. Progress towards stockpile declarations

In the United States, concerns about the potential for rapid breakout from the START I Treaty and about the safety and security of nuclear weapons and fissile material came to the fore during the Senate ratification debate in 1992. The Biden Amendment to the US resolution of ratification called for cooperative arrangements between the parties to monitor the number of stockpiled nuclear weapons and fissile material production and processing facilities.[6]

In December 1993 German Foreign Minister Klaus Kinkel proposed the establishment of a 'nuclear weapons register' to promote transparency in all stockpiles of nuclear weapons.[7] The USA rebuffed this initiative. At the same time, however, it began to urge Russia to agree to greater transparency, to fulfil the requirements of the Biden Amendment, to facilitate US assistance under the Cooperative Threat Reduction (CTR) programme and to bolster international support for the indefinite extension of the NPT. In September 1994 presidents Clinton and Yeltsin agreed to 'exchange detailed information . . . on aggregate stockpiles of nuclear warheads, on stocks of fissile materials and on their safety and security. The sides will develop a process for exchanging this information on a regular basis'.[8] The USA presented a draft text for such an agreement to Russia in June 1995. The agreement called for an exchange of data, on a confidential basis, on current total inventories of warheads and fissile materials, as well as the total number of nuclear weapons dismantled each year since 1980 and the type and amount of fissile material produced each year since 1970. Unfortunately, Russia declined to discuss the draft. According to the US chair of the joint working group, some Russian members of the group 'gave the impression that the scope of the data exchange went well beyond what they were prepared to consider'.[9]

The USA nonetheless continued to press for stockpile declarations and in 1997 Clinton and Yeltsin agreed to negotiate a START III treaty that would include 'measures relating to the transparency of strategic nuclear warhead

[6] *The START Treaty*, US Senate Executive Report 102-53 (US Government Printing Office: Washington, DC, 1992, 18 Sep. 1992), p. 101. For the Biden Amendment see section III of chapter 5 in this volume. The amendment was interpreted to apply to a future START III accord, since the START II negotiations were moving to a conclusion at that time. See also Lockwood, D., 'Senate ratifies START agreement; sets groundwork for deeper cuts', *Arms Control Today,* vol. 22, no. 8 (Oct. 1992), pp. 30, 38.

[7] Müller, H., 'Transparency in nuclear arms: toward a nuclear weapons register', *Arms Control Today,* vol. 24, no. 8 (Oct. 1994), pp. 3–7.

[8] Joint Statement on Strategic Stability and Nuclear Security by the Presidents of the United States of America and the Russian Federation, The White House, Office of the Press Secretary: Washington, DC, 28 Sep. 1994, p. 3, available at URL <http://csf.colorado.edu/dfax/npn/npn13.htm>.

[9] Goodby, J. E., 'Transparency and irreversibility in nuclear warhead disarmament', ed. H. A. Feiveson, *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons* (Brookings Institution Press: Washington, DC, 1999), p. 186.

inventories'.[10] They also agreed to explore, as separate issues, transparency measures for non-strategic nuclear warheads and nuclear material. Further progress on START III during the Clinton Administration was hindered predominantly by disagreements over missile defence.

Rather than continue these negotiations, in May 2002 presidents George W. Bush and Vladimir Putin signed the Strategic Offensive Reductions Treaty (SORT), which does not address non-deployed or non-strategic warheads and does not include verification provisions of any kind. It does, however, limit to 2200 the number of operationally deployed strategic warheads, and the Bilateral Implementation Commission which was established by the SORT may ultimately formulate measures to verify complicance with this limit.

Although no formal agreements on stockpile declarations have been concluded, some data have been released on a voluntary basis. None of the nuclear weapon states (NWS) has revealed the precise number of nuclear warheads in its current stockpiles, but France, the UK and the USA have released enough information to allow their warhead holdings to be estimated with reasonable accuracy. The USA is the most transparent, having released an official account of the total number of nuclear warheads in its stockpile each year from 1945 to 1961, the total yield of the stockpile, the number of warheads retired or dismantled from 1945 to 1994 and, for fully retired warhead types, the number assembled each year.[11] The USA has also provided data on its historical production and current inventories of military plutonium and highly enriched uranium (HEU).[12] A major motivation for the publication of these data was to encourage the other NWS to do the same. So far, only the UK has done so, issuing a detailed account of its plutonium stockpile and stating that in the future it would maintain fewer than 200 operationally available warheads of a single type.[13] The release of similar information by other NWS would go a long way towards achieving the goals of stockpile declarations.

III. Definitions

A stockpile declaration would involve an exchange of information between states regarding their inventories of nuclear warheads and materials. Before turning to the details of what might be included in such an exchange and how it

[10] Joint Statement on Parameters on Future Reductions in Nuclear Forces, The White House, Office of the Press Secretary, Washington, DC, 21 Mar. 1997, available on the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/resources/summits6.htm#parameters>.

[11] US Department of Energy, 'Declassification of certain characteristics of the United States nuclear weapon stockpile', URL <http://www.osti.gov/html/osti/opennet/document/press/pc26.html>.

[12] US Department of Energy, *Plutonium: The First 50 Years* (note 2); and US Department of Energy, 'Openness press conference: fact sheets' (note 2). A more detailed accounting of HEU production and inventories has been prepared for public release but is not yet available.

[13] British Ministry of Defence, *Strategic Defence Review,* July 1998, Chapter 4: Deterrence and disarmament, URL <http://www.mod.uk/issues/sdr/deterrence.htm>; and British Ministry of Defence (note 2).

might be accomplished, it is important to be clear about what is meant by the terms ‘nuclear warhead’ and ‘nuclear material’.

Nuclear warheads

The terms ‘nuclear warhead’, ‘nuclear weapon’ and ‘nuclear explosive device’ have not been defined with much precision in existing international treaties. As noted above, Russian–US nuclear arms control agreements have been concerned mainly with limiting nuclear delivery vehicles and their launchers; the corresponding number of deployed warheads was implied by means of counting rules that attribute a certain number of warheads to each type of delivery vehicle. In the START I Treaty, the term ‘warhead’ is defined simply as ‘a unit of account used for counting’;[14] according to the US State Department, ‘the term is never used to describe a physical object’.[15]

Similarly, the NPT refers to ‘nuclear weapons or other nuclear explosive devices’ but offers no definition for these terms. The most complete definition is given in the 1985 South Pacific Nuclear Free Zone Treaty (Treaty of Rarotonga) and the 1996 African Nuclear-Weapon-Free Zone Treaty (Treaty of Pelindaba): ‘“nuclear explosive device” means any nuclear weapon or other explosive device capable of releasing nuclear energy, irrespective of the purpose for which it could be used. The term includes such a weapon or device in unassembled and partly assembled forms, but does not include the means of transport or delivery of such a weapon or device if separable from and not an indivisible part of it’.[16] The 1967 Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Treaty of Tlatelolco) contains a similar definition.[17]

A stockpile declaration could resolve this issue in several ways. Parties could simply agree to declare all ‘nuclear weapons or other nuclear explosive devices’, in which case the term would be defined operationally: an object is a nuclear weapon if it is declared to be one; otherwise it is not. This has the virtue of simplicity, but it raises the question of how a party would demonstrate that an item is or is not a ‘nuclear explosive device’ if a dispute arose. If parties

[14] US Department of State, ‘Definitions annex’, URL <http://www.state.gov/www/global/arms/start htm/start/defini.html>.

[15] US Department of State, ‘Article-by-article analysis of the annex on terms and their definitions: structure and overview of the annex’, URL <http://www.state.gov/www/global/arms/starthtm/start/abadefin.html>. When referring to physical objects, the START I Treaty uses the terms ‘reentry vehicles’ or ‘heavy bomber armaments’ instead of ‘warheads’.

[16] US Department of State, ‘South Pacific Nuclear Free Zone Treaty’, URL <http://www.state.gov/www/global/arms/treaties/spnfz.html>; and US Department of State, ‘The African Nuclear-Weapon-Free Zone Treaty (The Treaty of Pelindaba)’, URL <http://www.state.gov/www/global/arms/treaties/afrinwfz.html>.

[17] ‘For the purposes of this Treaty, a nuclear weapon is any device which is capable of releasing nuclear energy in an uncontrolled manner and which has a group of characteristics that are appropriate for use for warlike purposes. An instrument that may be used for the transport or propulsion of the device is not included in this definition if it is separable from the device and not an indivisible part thereof.’ US Department of State, ‘Treaty for the Prohibition of Nuclear Weapons in Latin America [and the Caribbean]’, URL <http://www.state.gov/www/global/arms/treaties/latin1.html>.

adopted a definition similar to that given in the nuclear weapon-free zone treaties, which includes unassembled or partly assembled devices, this would raise an additional problem: at exactly what point would disassembled warhead components cease to be counted as a warhead? One possibility is to count the disassembled components as a warhead until a vital element (e.g., the high explosive) is destroyed or the fissile components are isolated and stored separately. Questions might also arise about laboratory, experimental or test devices which are not intended for military use but which might be considered, perhaps with some modification, as 'explosive devices'.

These difficulties and ambiguities would not be important in the initial phases of a stockpile declaration, before inspections or other measures are allowed to confirm the accuracy and completeness of the declaration. In later stages, however, it would be important to be able to demonstrate to inspectors that an item which is declared to be a warhead actually is a warhead and that other objects are not warheads. Two approaches to this problem are discussed below. The first uses an agreed set of characteristics or 'attributes' to define and identify warheads. The second approach uses a set of characteristics to define a unique fingerprint or 'template' for each type of warhead.

Nuclear materials

All nuclear weapons contain fission explosives, which use materials that can sustain a fast-fission chain reaction. By far the most common such materials are plutonium and HEU. The International Atomic Energy Agency (IAEA) refers to these as 'special fissionable materials',[18] the US Department of Energy uses the term 'special nuclear materials',[19] and 'fissile materials' has recently come into common use.[20] All these terms include plutonium and HEU, but they exclude certain other materials which, at least in theory, could be used to build a fission explosive. In this chapter, for reasons of simplicity, the term 'fissile

[18] 'The term "special fissionable material" means plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine.' IAEA, Statute of the International Atomic Energy Agency (as amended up to 28 Dec. 1989), Article XX, URL <http://www.iaea.org/worldatom/ Documents/statute.html>.

[19] 'The term "special nuclear material" means (1) plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 2071 of this title, determines to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing, but does not include source material' (section 2014aa). 'The Commission may determine from time to time that other material is special nuclear material in addition to that specified in the definition as special nuclear material. Before making any such determination, the Commission must find that such material is capable of releasing substantial quantities of atomic energy . . .' (section 2071). United States Code, Title 42, Chapter 23, URL <http://uscode.house.gov/title_42.htm>.

[20] Fissile materials are those that can be fissioned by neutrons of any energy and which therefore can sustain a slow-fission chain reaction, as occurs in most nuclear reactors. Fissionable nuclides have a minimum energy threshold below which they will not fission. Fissile nuclides are also fissionable, but fissionable nuclides are not necessarily fissile. Plutonium-239 and -241, uranium-233 and -235, and americium-243 are examples of fissile (and fissionable) nuclides, while plutonium-238, -240 and -242, neptunium-237 and americium-241 are examples of fissionable nuclides that are not fissile.

materials' is used to refer to any materials that can be used for nuclear explosive purposes.[21]

Fissile materials are essential ingredients of nuclear weapons. They are the most difficult and expensive part of a nuclear weapon to produce and manufacture. For this reason, control of and accounting for fissile materials are the basis for IAEA safeguards agreements to verify the compliance of NNWS with the NPT.

Declarations of fissile material inventories are an important complement to declarations of warhead stockpiles, for several reasons. First, the size of these stockpiles places an upper limit on the number of nuclear weapons a state can manufacture and is an indication of the potential of a state to increase its nuclear arsenal. Second, declaring such materials makes the precise definition of 'nuclear warhead' less significant because the most important parts of the warhead—the plutonium and HEU components—would continue to be declared and accounted for even after the warhead is disassembled. Third, because the difficulty of gaining access to these materials is the largest barrier to the spread of nuclear weapons to additional states, fissile materials should be held to the same standards of safety and security as nuclear weapons. Declarations make it easier to gain confidence that states are meeting these high standards. Finally, declarations by the NWS would remove one element of what some see as the discriminatory nature of the NPT and IAEA safeguards, which require NNWS to declare and subject their stocks of fissile materials to international accounting.

All current nuclear weapons contain weapon-grade plutonium and/or HEU (plutonium and uranium containing more than 90 per cent of the fissile isotopes plutonium-239 and uranium-235, respectively). A fission explosive can be built using plutonium or uranium containing much lower percentages of these fissile isotopes but with some ensuing decrease in yield, safety and reliability and an increase in the size and mass of the weapon.[22] A nuclear material declaration should therefore include all stocks of plutonium[23] and all stocks of uranium containing 20 per cent or more uranium-235 and/or uranium-233. Because the ease with which plutonium and HEU can be used for weapons depends on their isotopic composition and their chemical and physical form, declarations should disaggregate stocks accordingly.

Limiting declarations to plutonium and HEU would be more than adequate as long as military stocks of these materials are large. As military stocks of plutonium and HEU shrink, however, it would become important to include other materials, such as neptunium and americium, which are less common and less

[21] A refinement would be to define such materials as those having a bare critical mass of less than 250 kg, which is approximately equal to that of uranium enriched to 20% uranium-235. For comparison, the bare critical masses of plutonium-239 and uranium-235 are about 10 and 50 kg, respectively.

[22] US National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994), pp. 36–37.

[23] An exception is plutonium containing 80% or more plutonium-238, which is used as a heat and power source in remote applications, such as deep space probes.

attractive but nevertheless can be used to build a nuclear weapon.[24] Because fissile materials are the most valuable constituents of nuclear weapons, declarations of other warhead materials or components, such as tritium inventories, would add little to the value of warhead and fissile material declarations.

IV. Declarations: a phased approach

The key issues in the implementation of a declaration are which countries would participate, what information they would exchange, whether the exchange would be formal or informal, how often the data would be updated and whether information would be released to the public or kept confidential between the parties. In each case it is probably best to adopt a phased approach, moving towards more comprehensive exchanges of information as stockpiles decrease and as mutual confidence increases.

Which countries?

The countries that might participate in nuclear warhead and material declarations can be divided into three groups: (*a*) the nuclear superpowers (Russia and the USA); (*b*) the NPT-defined NWS (the superpowers plus China, France and the UK); and (*c*) the NWS (the previous five states plus the de facto nuclear weapon states, India, Israel and Pakistan). All other states have committed themselves, by ratifying the NPT, not to possess nuclear warheads and to place under IAEA safeguards all stocks of fissile material under their control.[25] It would make little sense to involve the NNWS in a declaration, but they may wish to have a role in determining the contents of a declaration and the availability of the resulting data.

Although a comprehensive declaration that includes all the NWS might be desirable, there are reasons why it may be preferable to begin in a less ambitious manner. First, there is a large disparity between the size of the nuclear superpowers' stockpiles and those of the other NWS and an equally large discrepancy in their experience in negotiating and implementing nuclear arms control agreements. This argues in favour of having Russia and the USA take the lead in formulating declarations, particularly more detailed declarations that might also involve verification measures. Their large and diverse stockpiles make it more important for them to engage in detailed declarations at an early stage, when the other NWS might be unwilling to do so. China, France and the

[24] Albright, D. and Barbour L., 'Troubles tomorrow? Separated neptunium 237 and americium', eds D. Albright and K. O'Neill, *The Challenges of Fissile Material Control* (Institute for Science and International Security Press: Washington, DC, 1999).

[25] There is a provision for the temporary withdrawal of nuclear materials from IAEA safeguards for non-explosive military purposes (e.g., a naval reactor), but this option has not been exercised. IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), IAEA document INFCIRC/153 (Corrected), June 1972, para. 14, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>.

UK might initially make only general declarations and wait until Russia and the USA have substantially reduced their stocks before joining in a more comprehensive declaration. The fact that China's current nuclear forces could not survive a first-strike attack if the locations of its warheads were known also argues against China's participation in all but the most general of declarations, until it deploys survivable forces.

Second, there is the sensitive issue of how to deal with the de facto NWS. Although there is little doubt that India, Israel and Pakistan possess nuclear weapons, they are not NWS under the NPT and there is great reluctance to acknowledge their nuclear status in any official way. More importantly, declarations of warhead or material stocks by these countries could be destabilizing. Transparency generally increases security only when states are reasonably comfortable with the status quo. Declarations by India and Pakistan could generate public pressure for nuclear superiority and trigger an arms race; declarations by Israel could fuel proliferation pressures in the Middle East. Harald Müller has suggested that the de facto NWS might declare only their stocks of nuclear materials,[26] but it is hard to see the advantages of such an arrangement given that knowledge of material stocks can easily be converted into worst-case assessments of warhead inventories. It may be preferable to defer declarations by the de facto NWS until such concerns are no longer considered as important or until they have agreed (perhaps together with the declared NWS) to eliminate their nuclear arsenals. In the meantime, attention can be focused on ending the production of fissile materials for military purposes and expanding the coverage of IAEA safeguards in these states.

What information?

Regardless of which countries participate, it is likely that declarations would begin with aggregated data and move in phases towards more detailed exchanges of information. Table 7.1 illustrates this progression using four levels of information: (*a*) aggregate inventories; (*b*) inventories by type and status; (*c*) inventories by facility; and (*d*) complete item-by-item inventories. In addition to current data, states may also wish to exchange historical information on inventories in order to build confidence in the accuracy and completeness of the declarations.

Level 1: aggregate inventories

The simplest data exchange would involve total numbers of warheads and the total mass of plutonium and HEU possessed by each state. Table 7.2 presents estimates of current stocks of warheads and materials in each of the NWS. Even at this very general level there are technical issues to resolve, such as whether unassembled or partly assembled warheads or explosive devices not intended

[26] Müller (note 1), pp. 17–18.

Table 7.1. Levels of information that could be included in declarations of nuclear warhead and fissile material inventories

Level	Nuclear warheads	Fissile materials
1	Current aggregate stockpiles	Current aggregate stockpiles
	Historical data on stocks, assembly, disassembly	Historical data on stocks, production, consumption
2	Warhead type, delivery system	Isotopic-grade (weapon-grade, etc.)
	Status (deployed, reserve, etc.)	Chemical form (metal, oxide, etc.)
		Physical form (pit, fuel, etc.)
	Historical data by type	Historical data by grade/form
3	Inventory by declared facility	Inventory by declared facility
	Facility descriptions	Facility descriptions
4	Serial number, location, status of each warhead	Location, mass, composition of each item or container

for military use would count as 'warheads', whether and how grades of plutonium and HEU below weapon-grade would be reported in data exchanges,[27] and how to resolve uncertainties in the data.

Regarding uncertainties, each of the NWS presumably knows the precise number of nuclear warheads it possesses, but, inevitably, there will be uncertainties regarding inventories of nuclear material. For example, the best estimate of the US plutonium inventory is 99.5 tonnes; although the amount of plutonium in fabricated weapon components and in containers of bulk material is known with high precision, there are substantial uncertainties (of the order of 1 tonne or more) regarding the amount of material in process tanks, piping, drains and ventilation ducts. Indeed, a material balance based on estimated total additions (111.4 tonnes) minus estimated total removals (9.1 tonnes) yields a predicted inventory of 102.3 tonnes.[28] The difference between the material balance and actual inventories—in this case 2.8 tonnes—is known as 'material unaccounted for' or the 'inventory difference'. There is no evidence that any of this plutonium has been lost or stolen; the inventory difference is largely or entirely due to the combined effects of errors in measurement and record keeping, overestimates of the amount produced in reactors and underestimates of the amount of plutonium in wastes. Inventory differences are likely to be relatively larger for HEU as compared to plutonium and for Russia as compared to the USA.

Although states might be reluctant to admit that inventory differences exist, it is better to reveal this information sooner rather than later in order to protect against suspicions that might arise if subsequent improvements in material

[27] As noted above, all grades of plutonium (except plutonium that contains 80% or more plutonium-238) and all HEU (20% or more uranium-235/233) should be reported in declarations. In table 7.2, HEU stocks have been converted to equivalent tonnes of weapon-grade HEU (93% uranium-235), based on the separative work required to produce the materials. However, it makes more sense for states to declare the actual mass of HEU in their stockpiles in order to simplify comparisons with more detailed declarations that may be made later.

[28] US Department of Energy, *Plutonium: The First 50 Years* (note 2).

Table 7.2. The number of warheads and military stocks of plutonium and HEU, 2000

The numbers are estimates.

Country	Warheads	Plutonium (tonnes)	HEU[a] (tonnes)
United States	10 500	99.5	635
Russia	20 000	130	970
United Kingdom	185	7.6	15
France	450	5	24
China	400	4	20
Israel	100	0.5	–
India	65	0.3	–
Pakistan	40	0.005	0.7

[a] Equivalent tonnes of weapon-grade HEU (93% uranium-235).

Sources: Natural Resources Defense Council (NRDC), 'Nuclear Notebook: Global nuclear stockpiles, 1945–2000', *Bulletin of the Atomic Scientists*, vol. 56, no. 2 (Mar./Apr. 2000), p. 79, URL <http://www.thebulletin.org/issues/nukenotes/ma00nukenote.html>; and Institute for Science and International Security, 'Production and status of military stocks of fissile material, end of 1999', URL <http://www.isis-online.org/mapproject/supplements.html>.

accounting change the estimated inventories significantly. Along with the best estimate of the actual total plutonium and HEU inventory, states might declare the inventory difference given by a material balance or the measurement error in the actual inventory, or they might simply declare an inventory range (e.g., 95–105 tonnes).

At this stage it would also be useful to declare historical inventories of warheads and materials in order to help build confidence in the accuracy and completeness of declarations of current inventories. States willing to share current data should also be willing to share historical data. Beginning with the year of their first nuclear test, states could give the total number of warheads assembled and disassembled each year and the number in the stockpile at the end of the year. Similarly, states could declare the total amount of plutonium and HEU produced or otherwise acquired each year, the total amount consumed or lost and the amount in the stockpile. This could be accompanied by a more detailed accounting of the material balance and the inventory difference.

In addition to historical data, states could exchange information on their plans to reduce inventories by dismantling warheads and transferring nuclear materials from military to civilian stockpiles. This has already been done to some extent for nuclear materials: Russia and the USA have both declared about 50 tonnes of plutonium excess to their defence needs and each agreed to transfer and dispose of 34 tonnes of weapon-grade plutonium from their military stockpiles. The USA has agreed to purchase low-enriched uranium (LEU) derived from 500 tonnes of HEU from dismantled Russian nuclear weapons. In addition, the USA has announced that 174 tonnes of HEU are excess to its

Table 7.3. The US warhead inventory, by type, 2000

The numbers are estimates.

		Number of warheads	
Warhead type	Delivery vehicle	Active	Inactive
B61-3/4/10	Tactical aircraft	710	640
B61-7/11	B-52, B-2 bomber	350	310
W62	MM-II ICBM	610	–
W76	T-I, T-II SLBM	3 200	–
W78	MM-III ICBM	915	–
W80-0	SLCM	290	–
W80-1	ALCM	800	780
B83	B-52, B-2 bomber	600	–
W84	–	–	370
W87	MM-III, PK ICBM	525	–
W88	T-II SLBM	400	–
Total		**8 400**	**2 100**

ALCM = air-launched cruise missile; ICBM = intercontinental ballistic missile; MM = Minuteman; PK = Peacekeeper; SLBM = submarine-launched ballistic missile; SLCM = sea-launched cruise missile; T = Trident.

Source: Norris, R. and Cochran T., Personal communication with the author, 14 May 2001.

defence needs, and the UK has declared an excess of 4.4 tonnes of military plutonium.[29]

Level 2: inventories by type and status

The next step would be to disaggregate total inventories by type and status. Nuclear warhead inventories could be given for each type of warhead, either warhead designator, delivery system, or both. A breakdown by status would also be desirable in order to differentiate between warheads that are in the 'active' stockpile and are considered ready for military use (i.e., mated with a delivery vehicle or ready to be mated, including spares and reserves) and warheads that are considered 'inactive' (e.g., in long-term storage or awaiting disassembly). An illustrative inventory of this type for the USA is given in table 7.3, based on unofficial estimates.

The situation is more complicated for fissile materials because these exist in various isotopic compositions and in various chemical and physical forms. At a minimum a distinction should be made between stocks of weapon-grade and non-weapon-grade plutonium and HEU, and it may be desirable to further dis-

[29] Bunn, M., *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Carnegie Endowment for International Peace: Washington, DC, and Harvard University: Cambridge, Mass., 2000), pp. 54–55, available at URL <http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>; and Institute for Science and International Security, 'Military fissile material declared excess', URL <http://www.isis-online.org/publications/puwatch/excessmil.html>.

aggregate non-weapon-grade material into several categories.[30] Regarding their physical and chemical form, plutonium and HEU can exist as fabricated weapon components (pits and canned sub-assemblies), either in assembled warheads or separately in storage; as bulk metals, oxides and other chemical forms; in fresh or irradiated reactor fuel; and in various wastes. Table 7.4 gives an approximate inventory of US military stocks of plutonium as of 2000.

As in level 1, it would be useful to release comparable historical information at this stage. For each type of warhead (including types not in the current stockpile), states could declare the number assembled and disassembled each year and the number in the active and inactive stockpiles. For fissile materials, states could release a more detailed material balance, disaggregating annual production and inventories by grade and by physical and chemical form. This type of accounting would be useful for improving the understanding of the inventory difference.

Level 3: inventories by facility

The next logical step would be to disaggregate inventories by location, which would be necessary before states could consider the possibility of inspections or other measures to confirm the accuracy of declarations. At this stage, states would declare all facilities at which nuclear warheads or materials exist and give a level-2 inventory for each facility. Descriptions and site diagrams could be exchanged, indicating the location of warheads and materials within each facility. If warheads or materials are located in more than one structure within a facility, the inventory could be further disaggregated. Russia and the USA have exchanged information at this level for nuclear delivery vehicles and launchers under the INF and START I treaties.

Declared facilities for warheads would include intercontinental ballistic missile (ICBM) bases, submarine bases, strategic bomber bases, warhead storage facilities at other military bases, and warhead assembly–disassembly facilities. A declaration similar to that illustrated in table 7.3 could be made for each of these facilities. For example, states would declare the total number of warheads of each type mounted on ICBMs or stored as spares at each ICBM base, the number deployed on submarines based at each port, the number of active and inactive warheads of each type in each storage facility, and so on.

Concerns about strategic stability could arise at this point if a state's nuclear forces could not survive a disarming first-strike attack. Declarations that include the location of every warhead might provide incentives for parties to launch an attack during a crisis, either to try to disarm another party or to use the warheads before they are destroyed.[31] This is not a concern for France,

[30] US Department of Energy, *Plutonium: The First 50 Years* (note 2). In the USA, plutonium is divided ,according to the percentage of plutonium-240, into weapon-grade (<7%), fuel-grade (7–19%), and reactor-grade (>19%) plutonium. HEU could similarly be divided into grades according to the percentage of uranium-235/233.

[31] This concern may even arise when exchanging level-1 information (total stockpiles). If, through national intelligence, an adversary had identified the locations of a certain number of warheads and knew,

Table 7.4. The US military plutonium inventory, by grade and form, 2000
Figures are in tonnes.

Physical, chemical form	Weapon-grade	Non-weapon-grade	**Total**
Fabricated components (warheads and pits)	66.1	–	**66.1**
Other unirradiated metal, bulk oxide and reactor fuel	18.3	7.6	**25.9**
Spent fuel	0.6	6.9	**7.5**
Total	**85.0**	**14.5**	**99.5**

Sources: US Department of Energy (DOE), *Plutonium: The First 50 Years*: *United States Plutonium Production*, *Acquisition, and Utilization from 1944 through 1994*, DOE/DP-0137 (DOE: Washington, DC, Feb. 1996), available at URL <http://www.osti.gov/osti/opennet/document/pu50yrs/pu50y.html>; and Author's estimates based on DOE and IAEA documents.

Russia, the UK and the USA, which maintain submarines at sea (and, in the case of Russia, mobile ICBMs) that cannot be targeted and destroyed. It could, however, be a concern for China and the de facto NWS, which may rely on uncertainty about the location of their warheads to deter an attack. Nuclear weapons might be moved in the time between declarations but, once their locations are known, national intelligence services would try to track these movements. This level of data exchange should therefore be deferred until a country is confident in the survivability of its nuclear forces.

Declared facilities for nuclear materials would include plutonium production reactors and reprocessing plants, uranium enrichment facilities, facilities where plutonium and HEU are chemically processed and fabricated into components, warhead assembly–disassembly facilities, waste storage facilities and storage facilities at other locations. A declaration similar to that shown in table 7.4 could be made for each facility, listing the amount of plutonium and HEU of each grade and form present at that location. A detailed account of the material balance and inventory difference could also be given for each facility.

Level 4: inventories by item

The ultimate declaration would be an itemized list of each warhead and each component or container of fissile material. For warheads, the declaration could take the form of a table with columns for warhead type, serial number and current location and with a row for each warhead in the stockpile. Information could also be provided about the history of the warhead, such as the date of its assembly as well as the dates and locations of the deployment or previous storage of the warhead; this might be extended to include warheads that have been

by virtue of the declaration, that this represented the state's entire inventory, it might be emboldened to launch a disarming attack.

dismantled. For nuclear materials, the declaration would give the mass, isotopic content, and chemical and physical form of each item. This declaration might draw directly on national systems of material accounting and control and be similar to the reports on inventories of civilian nuclear material that are provided to the IAEA. Indeed, procedures might be worked out to give other states controlled access to the databases that are used to track nuclear warheads and materials.

At present, this level of detail would be considered highly sensitive, particularly regarding information on warheads. However, sharing and confirming this level of information are prerequisites for an agreement to prohibit nuclear weapons. One of the most difficult technical issues associated with prohibition is gaining high confidence in a state's baseline inventory of nuclear warheads and nuclear materials. Once the baseline is established, prohibition can be achieved by verifying that all warheads contained in the baseline inventory have been destroyed and that all nuclear materials have been placed under international safeguards.[32]

Although states may not be willing to share information as detailed as this in the near future, encryption technology makes it possible to exchange data without revealing their contents. As discussed in chapter 8, parties could exchange at an early date an encrypted declaration containing an agreed set of detailed data and then allow only selected portions of the data to be decrypted in stages or upon request. Russia and the USA could, for example, periodically exchange complete but encrypted itemized declarations of their nuclear warhead and material inventories. In the first stage, they could provide each other with a key that would allow only the total number of warheads and total amount of plutonium and HEU to be decrypted. Next, they could exchange keys that would allow the totals, by type and facility, to be decrypted, for both current and past declarations. At later stages a party could request that detailed information be decrypted for a sample of the individual items. By verifying the accuracy of the declaration for a relatively small random sample of items, parties could gain confidence in the accuracy of the entire declaration even while most of it was still encrypted. Only in the final stage would all data from all declarations that had been exchanged be decrypted.

Formal or informal?

As noted above, the UK and the USA have voluntarily released some information (below level 1) on their inventories of nuclear weapons and considerable data (up to levels 2 and 3) on their stockpiles of nuclear materials. France has released information on the size and nature of its deployed nuclear forces, but not on the size of its stockpiles of nuclear warheads or materials. The secrecy culture is so strong in China and Russia that it seems unlikely that they would

[32] Fetter, S., *Verifying Nuclear Disarmament*, Occasional Paper no. 29 (Henry L. Stimson Center: Washington, DC, Oct. 1996).

release information about their nuclear stockpiles without a compelling reason or incentive. This does not rule out the possibility of an informal exchange of data, but it does mean that any voluntary release of information would probably have to be part of a larger initiative. For example, the USA might link its willingness to reduce the size and launch readiness of its nuclear forces or the provision of certain US assistance to Russia (e.g., for improving nuclear material accountancy) to the mutual release or exchange of authoritative data on warhead and material stockpiles. Although it is difficult to imagine a similar quid pro quo for China, it may feel compelled to release at least level-1 information, such as total inventories of plutonium or HEU and perhaps the total number of warheads, if the other declared NWS have done so.

Although an informal exchange of data might work initially, when the data are not very detailed or sensitive, a formal agreement would become more important as declarations become more detailed. It would therefore be essential to allow inspections or other procedures to verify their accuracy and completeness. Although formal negotiations are time-consuming and can delay the realization of transparency and confidence-building measures, the Russian–US unilateral reductions in non-strategic nuclear weapons demonstrate the drawbacks of an informal understanding. Russia and the USA probably interpreted and implemented these reductions in different ways and, despite their assurances that they would keep each other informed about progress in implementation, they have exchanged little information to this end.[33]

How frequent?

Initial informal declarations might be sporadic or a one-off affair, but a more formal arrangement would provide for the regular exchange or updating of declarations at agreed intervals. Six months would be an appropriate interval for declarations of warhead and material inventories, inasmuch as the INF and START treaties established a six-month interval for the exchange of data on the number of deployed delivery vehicles and launchers. IAEA safeguards agreements also require biannual statements of inventories of nuclear materials.

As inventories of nuclear warheads and materials are reduced, there may be a need for more frequent exchanges of information, since relative changes in a given period could be much greater for smaller inventories. If states move towards itemized declarations, it might be feasible to update declarations continuously or in real time, particularly if other parties are given controlled access to a state's inventory control system for tracking warheads or materials. For example, one could imagine a system that would continuously and automatically monitor warheads in a storage area and which could report this information on a real-time basis to other parties.

[33] See, e.g., Gottemoeller, R., 'Lopsided arms control', *Washington Post*, 7 Dec. 2000, p. 21; and Potter, W. and Sokov, N., 'Tactical nuclear weapons: the nature of the problem', 4 Jan. 2001, URL <http://cns.miis.edu/pubs/reports/tnw_nat.htm>.

Public or confidential?

The voluntary declarations by the UK and the USA were made public partly because they were intended to inform and influence domestic and foreign public opinion. The information exchanged by Russia and the USA under the INF and START I treaties was also made public. Reports to the IAEA of inventories of materials under safeguards, on the other hand, are kept confidential, presumably to protect proprietary information. Although there are no commercial interests in warhead or military nuclear material inventories, there is a strong interest in preventing the release of information that could be useful to states or groups interested in acquiring nuclear weapons. The US proposal in 1995 called for a confidential exchange of data between Russia and the USA on warhead and material inventories.[34]

Although it might appear that the USA would be willing to share with its citizens any information it was prepared to share with the governments of China or Russia, and vice versa, this is not so certain. Since the declared NWS already know how to build sophisticated nuclear weapons, there might be some design information, such as the amount of plutonium or HEU in a collection of warheads or a particular type of warhead, that they might be willing to share with each other but not with NNWS (and, perhaps, not with the de facto NWS). Similarly, there might be information about nuclear materials, such as the precise locations where they are stored or the measures that are used to protect or account for them, that the NWS might be willing to share with each other but not more generally, for fear that such information might aid someone wishing to steal or divert material. States might also fear that releasing information on the locations of their nuclear weapons could trigger public opposition and protests. For example, the USA might be particularly reluctant to reveal the locations of its nuclear weapons based in Europe.

Confidential declarations can bring about many of the security benefits of increased transparency but, to the degree that declarations are intended to reassure the public and NNWS governments that the NWS are reducing their inventories of nuclear weapons and materials and managing them responsibly, they should be made as openly available as possible. The presumption should be in favour of making information public unless there is a compelling reason to keep it secret. It is hard to see why aggregate numbers of warheads or materials by type and facility—the level-2 and level-3 information discussed above—should not be shared with the entire world, if it can be shared among the NWS .

V. Verification

Stockpile declarations could serve as important confidence-building measures even without inspections to verify their accuracy. Voluntary declarations made

[34] Goodby (note 9).

at an early date are likely to be accepted at face value. This is particularly true for Russia and the USA, which have much larger stockpiles than they require for their defence and therefore would have little reason or incentive to cheat. Moreover, all of the NWS, unless they have compelling reasons to cheat, should be deterred from making false declarations by the possibility that later inspection would reveal such falsification.

If states wish to establish agreed limits on stockpiles of nuclear warheads and materials, however, it would be highly desirable to verify the accuracy and completeness of declarations. In order for verification to be possible, declarations must contain inventories for each declared facility; an itemized declaration would be even better. Chapters 8 and 10 discuss this topic in detail but a brief introduction to some of the issues is given here.

Nuclear warheads generally are mounted on delivery vehicles or are located in storage bunkers. The number mounted on delivery vehicles could be verified using procedures similar to those established by the START I Treaty. For example, START I provides for visual inspections of the front sections of ICBMs and submarine-launched ballistic missiles (SLBMs) to verify that they are not armed with more than the permitted number of warheads. Such inspections could be adapted to verify the actual number of nuclear weapons on missiles or bombers.

Nearly all other warheads are in storage facilities. In this case, inspections would mostly involve visiting a particular storage facility to confirm that the declared number of warheads is present—no more, no less. Similar procedures would apply to fabricated plutonium and HEU components (pits and canned sub-assemblies), most of which are stored in sealed containers in a few storage facilities.

Inspections of storage facilities would be simplified if each warhead or canister was marked with an unique identifier. The serial number could serve as such an identifier, or special 'tags' could be used for this purpose.[35] Tags would have two key advantages. First, they would make it easier to certify the completeness of a declaration because the discovery of a warhead or canister without a valid tag would constitute unambiguous evidence of a violation. Second, it would not be necessary to inspect or count every item to gain confidence in the accuracy of the declaration. Inspectors could instead use the tags to select a random sample, greatly reducing the inspection effort and its degree of intrusiveness. If, for example, the inspection of a random sample of 20 or 30 warheads did not reveal any undeclared or bogus warheads, there would be a high level of confidence that the entire declaration was accurate.[36]

[35] See Fetter, S. and Garwin, T., 'Tags', eds R. Kokoski and S. Koulik, SIPRI, *Verification of Conventional Arms Control in Europe: Technological Constraints and Opportunities* (Westview Press: Boulder, Colo., 1990), pp. 139–54.

[36] Assume that 10% of the warheads at a particular site have invalid tags. If the total number of warheads at the site is large (>400), the probability that a random sample of 20 warheads would include at least 1 invalid warhead is 88%; for a sample of 30 warheads, the probability is 96%. The general formula is $P = 1 - (1-F)^n$, where F is the invalid fraction, n is the number sampled, and P is the probability that the sample contains at least 1 invalid warhead. The probability is greater if the total number of warheads is

A tagging scheme could make use of existing surface features (at sufficiently high magnifications all surfaces have a unique 'fingerprint') or several different kinds of applied tags, such as bar-coded labels or plastic holographic images overlaid by a tamper-proof tape. Tags were used by the United Nations Special Commission on Iraq (UNSCOM) to log and track items which could be used for both civilian and military purposes and are used routinely by the IAEA to safeguard civilian nuclear materials. The use of tags for verification of mobile missiles is provided for in the START I Treaty.[37] Although certain technical issues would have to be worked out, there should be no problem in instituting an effective tagging system for canisters containing nuclear warheads, warhead components or nuclear materials.

A key problem in confirming a declaration is knowing that a declared item is authentic—for example, that an object which is declared to be a warhead really is a warhead—without revealing sensitive weapon design information. There are two general approaches to this problem.

The first approach would make use of an agreed set of attributes that each type of item should display. For example, it might be agreed that a plutonium pit should contain a minimum amount of plutonium metal with a certain maximum concentration of plutonium-240 in a symmetrical shape. To protect sensitive information, an automated system could be used to measure the attributes and produce a simple 'yes' or 'no' answer to the question, 'Does the object display the agreed set of attributes?'. A system of this type was developed by Russian and US laboratories to confirm the authenticity of plutonium pits to be placed in a US-funded storage facility near Chelyabinsk. The use of radiation detection devices is provided for in START I to confirm that certain objects are or are not nuclear warheads; in this case, the only attribute is the presence of radiation.

The second approach would make use of 'fingerprints' or 'templates' for particular types of warheads or fabricated components. For example, Russia could present one or more SS-18 warheads for fingerprinting, or warheads could be selected from a deployed missile by inspectors. A set of agreed characteristics could be measured: length and diameter; mass and centre of gravity; neutron and gamma-ray emissions; heat output; or its ultrasonic signature. A template based on a variety of characteristics would make it extremely difficult to cheat. Again, weapon-design information could be protected with an automated system that would compare an object with the template and produce a 'yes' or 'no' answer.[38]

small; e.g., if the site contains only 50 warheads, the probability that at least 1 of 20 would be invalid is 93%. The general formula in this case is $P = 1 - [(N-M)!(N-n)!]/[(N-M-n)!N!]$, where N is the total number of warheads and M = FN is the number of invalid warheads.

[37] Annex 6 to the Inspection Protocol of START I, which describes procedures for associating unique identifiers with mobile missiles or their launch canisters, defines a unique identifier as 'a non-repeating alpha-numeric production number, or a copy thereof, that has been applied by the inspected Party, using its own technology'.

[38] The Controlled Intrusiveness Verification Technology (CIVET) system developed at Brookhaven National Laboratory accomplishes this task with a high-resolution gamma-ray detector and a special-

The verification procedures discussed above would apply to warheads and fabricated components, which require the protection of sensitive weapon design information. Declarations of fissile materials in other forms—plutonium and HEU in metal scraps, oxides, reactor fuel elements and various wastes—can be confirmed with the standard non-destructive assay (NDA) techniques used by the IAEA. An exception might be naval reactor fuel, the design of which is currently considered a military secret. In this case, an automated system could use NDA measurements to confirm that the declared amount of HEU or plutonium was present in the fuel without revealing the details of its design.

More challenging than confirming the accuracy of a declaration is demonstrating its completeness—in other words, demonstrating that there are no hidden or undeclared warheads or stockpiles of nuclear material. Challenge, or anytime–anywhere, inspections are often mentioned as one way to detect undeclared stockpiles if they exist, but a well-designed plan to hide warheads or materials would provide few clues about where to look. One could monitor existing warhead maintenance or tritium-production facilities, but warheads could be maintained elsewhere and a 30-year stockpile of tritium could be kept with the warheads.

A better approach is to exchange detailed historical information on the nuclear stockpiles as part of the declaration. These historical declarations could be examined for internal consistency and for consistency with the current stockpile declarations and archived intelligence information. Inspectors could also request a sample of the original operating records of production facilities to determine their authenticity and their consistency with the declarations. The IAEA used this approach to help confirm the completeness of South Africa's declaration of its HEU stocks after South Africa dismantled its nuclear weapons and joined the NPT.[39]

In some cases, inspections might be able to confirm the completeness of declarations more directly. For example, measurements of isotope ratios in the permanent structural components of a reactor can verify declarations of the total production of plutonium at that reactor.[39] Similarly, isotope ratios in depleted uranium stored at enrichment facilities can help confirm declarations of HEU production.

purpose computer without permanent memory. *Brookhaven Bulletin*, vol. 52, no. 39 (9 Oct. 1998), p. 3, available at URL <http://www.bnl.gov/bnlweb/pubaf/bulletin/1998/bb100998.pdf>.

[39] South Africa joined the NPT in July 1991 and submitted to full-scope IAEA safeguards. A specially appointed IAEA team visited South Africa to carry out inspections in Nov. 1991. In Mar. 1993, South African President Fredrik Willem de Klerk announced that South Africa had developed and subsequently dismantled a 'limited nuclear deterrent capability' involving the design and manufacture of 7 gun-assembled devices. The IAEA, following successive verification activities, concluded that the South African nuclear weapon programme was completely terminated and dismantled. von Baeckmann, A., Dillon, G. and Perricos, D., 'Nuclear verification in South Africa', *IAEA Bulletin,* vol. 37, no. 1 (1995), p. 42, URL <http://www.iaea.org/worldatom/Periodicals/Bulletin/Bull371/baeckmann.html>.

[39] Fetter, S., 'Nuclear archaeology: verifying declarations of fissile-material production', *Science & Global Security*, vol. 3, nos 3–4 (1993), pp. 237–59; and Talbert, R. J. *et al., Accuracy of Plutonium Production Estimates from Isotope Ratios in Graphite Reactors,* PNL-RTC 0693 (Pacific Northwest Laboratory: Richland, Wash., Feb. 1995).

The manner in which inspections and other verification procedures would be conducted would depend primarily on which states were parties to the regime. If such a verification regime is limited to Russia and the USA, as seems likely, at least initially, inspections could be conducted on a bilateral basis, as in the INF and START I treaties. If additional NWS are involved, a choice must be made between decentralized and centralized inspection procedures. The former is an extension of the bilateral model: each party would exchange information with every other party and each party could request inspections of any other party. The number of inspections that each party could request or would be obligated to receive could be limited and inspections could be conducted jointly by more than one state. This inspection model is used in the 1990 Treaty on Conventional Armed Forces in Europe. Although this model would make it easy to prevent the release of weapon design information, some would view it as a cabal designed to protect the interests of the NWS, with no accountability to other members of the NPT.

Alternatively, a central authority could be established to conduct inspections. This model is used to verify compliance with the CWC and the NPT. Although the IAEA might naturally be seen as the proper organization to receive and verify stockpile declarations, the involvement of personnel from NNWS would be a major obstacle. The IAEA's role might therefore be limited to verifying declarations of items, such as plutonium and HEU in bulk forms, that do not involve sensitive military information. Alternatively, or in addition, an inspectorate could be formed under IAEA auspices using personnel drawn from the NWS and reporting directly to the IAEA Director General. Such arrangements could partly address the concerns of the NNWS for wider accountability while protecting sensitive weapon design information.

VI. Conclusions

The exchange of stockpile declarations is the next logical step in nuclear arms control. To date, only the strategic nuclear delivery vehicles and launchers deployed by Russia and the USA have been subject to quantitative limits. As nuclear arsenals are reduced, more attention must be focused on nuclear warheads and their essential ingredients, fissile materials. Declarations of nuclear warhead and material inventories would improve international security and stability by ameliorating concerns about breakout from the strategic nuclear arms control treaties, building confidence in agreements to reduce non-strategic nuclear weapons, facilitating cooperation to improve the safety and security of nuclear weapons and materials, and bolstering the non-proliferation regime.

The NWS should be encouraged to exchange information on their inventories of nuclear warheads and materials. This can be accomplished in phases, beginning with the provision of data on current and historical aggregate stockpiles, then disaggregating their inventories by type and facility, and ultimately moving to declarations that list each item. In the later stages, when inventories become more detailed, states could allow inspections to confirm the accuracy and completeness of the declarations. Verification measures would be required if quantitative limits were imposed on the number of warheads or amount of fissile material that could be held by each NWS.

It is important to begin the process of exchanging stockpile data as soon as possible. Early declarations, even those of a very general nature, would build confidence and stimulate governments to improve their internal accounting systems. In the case of historical information, such as the production of nuclear warheads or materials in past decades, it is important to assemble this type of data today, while the personnel who were involved in these operations are still available to resolve any discrepancies or uncertainties that might arise.

Although stockpile declarations will undoubtedly present numerous challenges, the task is manageable if the NWS do the necessary technical work and negotiate in good faith. Unlike past Russian–US nuclear arms control agreements, which were discrete events, increased transparency should be seen as a continuous process, in which the exchange of information is constantly increased and ways are found to corroborate that information. This process is an essential component of a long-term programme to reduce the size and significance of nuclear arsenals and strengthen the non-proliferation regime.

8. Technologies and procedures for verifying warhead status and dismantlement

Richard L. Garwin

I. Introduction

This chapter describes ways in which compliance with a cooperative regime limiting the numbers and locations of warheads can be assured. The techniques and procedures considered here could be used both to monitor compliance with a formal treaty and to serve the goal of transparency.

The states which possess nuclear weapons will not easily accept measures that increase the vulnerability of warheads or impair their readiness for use. On the other hand, if there were major security gains in a posture of reductions and constraints on the use of nuclear weapons, states might choose to join such agreements, in the process sacrificing some flexibility with regard to their warheads. Nuclear disarmament agreements would be more seriously considered if there were tools for providing adequate transparency. A control and accounting regime is not only attractive from the perspective of a state's own security interests but also a necessary element of agreements limiting nuclear warheads. If warheads are banned rather than limited, verification becomes a much simpler task.

Over the past half-century, tens of thousands of nuclear warheads have been disassembled, but many of them have been recycled as warheads of a different type or even re-manufactured. Nuclear warheads undergo a life cycle that includes manufacture, storage, deployment, then storage again, followed by disassembly and re-manufacture or transfer into weapon-grade fissile material stockpiles. Transportation is involved between each of these stages. In the normal course of events, warheads may be routinely re-manufactured after 10 years (as is reported to be the case with Russian nuclear weapons) or inspected and modified as necessary (as in the case of US nuclear weapons).

In connection with the US Stockpile Stewardship Program, a wealth of information has been released by the Department of Energy and in the unclassified reports of the JASON group of consultants to the US Government.[1] A recent report is also available from the British Atomic Weapons Establishment.[2]

[1] US Department of Energy (DOE), 'Fiscal year 2000 stockpile stewardship plan, executive overview', Mar. 1999, available at URL <http://www.dp.doe.gov/dp_web/documents/overview.pdf>. The JASON group of about 50 largely academic scientists consult with the DOE and other parts of the US Government. Several of its unclassified publications have been posted by the author at URL <http://www.fas.org/rlg>.

[2] British Atomic Weapons Establishment (AWE), *Confidence, Security and Verification: The Challenge of Global Nuclear Weapons Arms Control*, AWE/TR/2000/001 (Aldermaston: Reading, Apr. 2000), available at URL <http://www.awe.co.uk/main_site/scientific_and_technical/publications/pdf_reports/awe_study_report.pdf>.

II. Outside the regime: covert warheads

In outlining the technologies and procedures for the verification of an agreed undertaking involving nuclear warheads, the warheads that have not entered the regime but are either hidden or maintained in active stockpiles and ready for use are a major concern. Furthermore, new warheads might be manufactured from weapon-grade fissile materials. Strict controls would be needed over stockpiles of fissile materials, most commonly plutonium or highly enriched uranium (HEU), and over facilities where fissile materials can be manufactured in order to contain the threat of material proliferation. Warheads are small, and even the smaller nations have numerous places in which they could clandestinely store a few dozen warheads, such as mines, conventional armouries or the basements of high-security government buildings not otherwise related to nuclear weaponry.

If a state does not intend to divert its nuclear warheads, this intention should be demonstrated by its own system of materials protection, control and accounting (MPC&A). MPC&A systems should be designed to be useful in a transparency regime.

If a state does intend to divert its warheads, however, it would have to both keep records and inform a limited number of individuals about the purpose of its covert store of nuclear weapons. Otherwise, these weapons would be of little use and of considerable hazard to its purpose. The state would also need to provide security, surveillance and, very likely, appropriate maintenance for the covert warheads, as well as the means to bring them out and mate them with delivery vehicles.

One way of deterring diversion is so-called societal verification.[3] This can be facilitated by making the text of treaties widely available in the states parties to them. Moreover, domestic law should make it illegal to conduct activities that a state has committed itself not to conduct. Individuals should be both allowed to and responsible for reporting state violations of agreements to a verification commission. Societal verification can also play a role in reinforcing the effectiveness of a transparency regime for warheads.

III. Establishing a verification regime

The elements of a regime for verification of an agreement limiting warheads and associated materials have been widely studied. Several types of agreement can be envisaged. One category would limit only the number of warheads of specific types, while others would limit not only warhead numbers but also, for example, the locations and state of readiness of the warheads. Even in a regime that limits only the number of warheads (e.g., to a total of a few thousand),

[3] Rotblat, J., 'Societal verification', eds J. Rotblat, J. Steinberger and B. Udgaonkar, *A Nuclear-Weapon-Free World: Desirable? Feasible?* (Westview Press: Boulder, Colo., 1993), pp. 103–18. See also section IV of chapter 10 in this volume.

individual warheads or amounts of fissile material would have to be identified. Hence there is a requirement for tags and seals—tags to show the claimed identity of a treaty-limited item (TLI), and seals to provide assurance, without great effort, that a TLI is present and has not been removed.

Because nuclear weapons and fissile materials are both dangerous and potentially valuable, a state should want to have an MPC&A system in place, regardless of whether it is a party to an agreement that limits them. If it is possible at a reasonable cost to tag and seal them and to report their identity and location to a higher authority, this would have merit outside any arms limitation agreement.

An analogy can be made with the regulation or taxation of automobiles. Without identifying marks, automobiles would have to be counted by bringing them all to a relatively small number of locations and arranging them in blocks of 10, super blocks of 100, and so on. This would establish that there were no automobiles at all outside the areas in which they were massed. However, automobiles have a tag (a licence plate) and a permanent identifier on the engine block, windscreen or frame, and in some states the licence plate is an official document. It can be seen from this analogy that the use of tags converts a limitation to a total ban—in this case a ban on non-tagged items.

In the case of treaty-limited nuclear weapons, with tags the TLIs no longer have to be brought to one place for counting. Moreover, it does not make sense to conduct an exhaustive enumeration of the TLIs. Instead, a sampling approach can be used to verify declarations.[4]

Once a nuclear warhead or package of fissile material has become a TLI and has a tag and a seal, the verification and transparency regime has much in common with any other MPC&A regime. Recent developments in information technology should make the transition to such a regime much more acceptable. The following quotation describes how this would work for a battalion, but the procedure would be similar for any unit controlling nuclear weapons.

> . . . an encrypted file [is] provided daily by each Bn [Battalion] to its headquarters and communicated to the other side. When decrypted, the lines in the table constitute a list of the TLI with their individual identification numbers. Each Bn (and, if desired, each line in the table) could have a different cryptographic key, so that there need be no valid concern about the inspecting side being able to break the code and obtain clear information about the details of deployment of every one of the TLI. In fact, schemes exist by which additional standard text is encrypted together with the information lines of the table, and alternate bits or characters deleted from the encrypted table, so that the information is just not there, even if the cryptographic key were communicated. Under these circumstances, the information in the table would only be available when provided in the clear by the inspected side. The encryption would serve simply as a means of validation of the clear text—the test being that the asserted clear text when

[4] Discussion of such approaches by the author can be found in Garwin, R. L., 'Tags and seals for arms control verification', Draft submitted to *Bulletin of the Council for Arms Control* (London), Oct. 1988, available at URL <http://www.fas.org/rlg/010208-sipri.htm>; and Garwin, R. L.,'Verification of limits on conventional forces in Europe (CFE)', Paper presented at a meeting of the Committee on International Security and Arms Control (CISAC) with a group from the Royal Society, London, 15 Mar. 1990, available at URL <http://www.fas.org/rlg/900315-cfe.htm>.

encrypted by the asserted key gives precisely the deposited cipher text. In principle, this scheme is analogous to a perfectly secure envelope that can be available at any time, that cannot be forged, and that cannot be destroyed.[5]

In principle, each TLI would have a corresponding line in a table, and each line in the table would correspond to a TLI. A party may have reasons to have dummy lines, for example, if it did not want to possess the full number of warheads permitted by the treaty. Lines in the table would contain the date and precise time, so that the encrypted version of two dummy lines would not be identical.

If each line in the table is encrypted with its own key by a standard encryption algorithm such as the triple digital encryption standard (triple-DES), it would be impossible to obtain any information without the key. In order to verify the accuracy of the listing, an inspector might be admitted to a chosen location where there was a warhead. The host nation would then identify the line in the encrypted file corresponding to that warhead and would provide the 168-bit key for decrypting the line. The line would then reveal the serial number of the tag, perhaps the serial number of the warhead itself, and the warhead location. All of this information would also be available to the inspector from the physical object.

The other part of the verification process would be based on sampling, to ensure that all the warheads were where they were claimed to be located. This would be accomplished by picking at random a line in the table, having it reveal the location of the particular weapon and freezing that weapon in place until it could be visually inspected.

Alternatively, the tag (or a cooperative communication system) could be used to communicate the identity and location of the object (verified by the Global Positioning System, GPS), thus reducing the cost and the intrusion of a visit.[6]

Additional improvements and simplifications might also be made to the system. For example, rather than relying on tags or seals for verifying that a TLI had not been moved after its encrypted line had been decrypted and its putative location had been established, a special device could be available where warheads are stored and could be put in place within minutes of a query; it would be equipped with sealed sensors that would show that neither the instrument nor the TLI had been moved or emplaced after the time of query.

However, very few rational, knowledgeable decision makers could be expected to consider exchanging all the identity and location information on all their warheads because it would be difficult to allay the concern that tables containing this information could come into the possession of an adversary and reveal secrets. Accordingly, a scheme has been devised in which so much of the information is deleted that there is no secret to be revealed.[7] The encrypted line (which in fact no longer needs to be encrypted) does not contain the informa-

[5] Garwin, 'Verification of limits on conventional forces in Europe (CFE)' (note 4).
[6] Garwin, 'Tags and seals for arms control verification' (note 4).
[7] Garwin, 'Verification of limits on conventional forces in Europe (CFE)' (note 4).

tion because it is too short—it serves only to validate the corresponding line in the table when it is ultimately revealed. This approach sacrifices nothing compared with possessing the encrypted data itself. After all, the side that owns the TLI could always refuse a request to decrypt that specific line.

The key to validating these tables is the Secure Hash Standard.[8] It specifies a Secure Hash Algorithm, SHA-1, 'for computing a condensed representation of a message or a data file', referred to as a message digest. A secure 'hash' is a smaller number of bits or characters derived from a message that depends on every character of the message in such a way that 'it is computationally infeasible to find a message which corresponds to a given message digest, or to find two different messages which produce the same message digest'.

The SHA-1 produces a 160-bit message digest from any message or file of a length less than 2 to the 64th power. This corresponds to 10 to the 19th power. Given that the average length of a novel is about 10 to the 7th power, SHA-1 is perfectly adequate to provide a digest of any of the messages that are of concern here. The Secure Hash Algorithm has been made public and has been reviewed extensively for its cryptographic adequacy. The owner of the TLI would therefore not be concerned about revealing information by providing the message digest.

The exchange of message digests can begin before there is an actual agreement to provide such information, but the message digest can at the same time be very useful to the owning country for its TLI protection, control and accounting. When the line corresponding to a TLI is provided in response to a query, or in response to an inspection of the TLI, the inspecting party would simply use SHA-1 to transform what is supposed to be the real information and determine whether the message digest produced in this way is the digest that has been provided in the table.

IV. Entry into the verification regime

A warhead or an amount of weapon-grade fissile material in a container could be entered into the verification regime by affixing a simple tag and noting the type and sub-type of the warhead and other detailed information. It might also be necessary to note the type of container and the orientation of the warhead within it. Deployed warheads, or warheads that are taken from containers and deployed, might have a tag affixed in an approved fashion and could also have a seal (such as a fibre optic purse) to provide assurance that the tag still refers to the same warhead.[9] Later, the system might acquire detailed information for validating the identity of the warhead.

[8] US Department of Commerce, National Institute of Standards and Technology (NIST), 'Secure Hash Standard', Federal Information Processing Standards Publication 180-1, 17 Apr. 1995, available at URL <http://www.itl.nist.gov/fipspubs/fip180-1.htm>.

[9] Garwin, 'Tags and seals for arms control verification' (note 4), pp. 3–5.

More specifically, assume that a number of containers have been claimed to contain a W-88 warhead in a Mk-5 re-entry vehicle. Two approaches are under consideration for verifying that the TLI contains the declared warhead.

The first approach is to measure certain 'attributes', which might include at least a minimum mass of fissile material. However, measurement of these attributes is so imprecise that it does not allow for reasonable verification or even transparency. For instance, if some warheads contain as little as 4 kg of plutonium, whereas others have as much as 6 kg, the attribute for plutonium would have to be set well below 4 kg so that few low-plutonium warheads would be rejected. Hypothetically, a 6-kg primary could be converted into a 4-kg warhead and the remaining 2 kg of plutonium sold, or two 6-kg primaries could be converted to three 4-kg primaries.[10] To the extent that an attribute system depends on tags and seals, later measurement of attributes can be dispensed with because, in the case of nuclear warheads, they add little information.

Considerably more confidence can be placed in a passport (Russian term) or template (US term) approach, which uses detailed, precise measurements of the radiation characteristics of the TLI. The data obtained are sufficiently detailed to provide useful information on the weapon design. While Russia and the USA might ultimately be willing to exchange such information, releasing it into an international system could advance nuclear weapon proliferation rather than inhibit it. The idea is therefore to have precision measurement combined with an information barrier. For instance, in 1989 the US Brookhaven National Laboratory demonstrated the Controlled Intrusiveness Verification Technology (CIVET) approach, using computers without persistent memories to make decisions without the release of sensitive data. This technology was demonstrated to Russian experts in 1997 at Oak Ridge in preparation for completion of the Mayak storage facility. Similar systems have been demonstrated at the Sandia National Laboratories and at the Pantex facility. Recent measurements taken with Sandia's Trusted Radiation Inspection System (TRIS) show the true potential of the template system in discriminating between 15 objects (8 pits, 5 fully functional bombs or re-entry vehicles, and 2 secondaries).

Figures 8.1–8.2 and tables 8.1–8.2 show some of the measurements made in the Russian–US joint experiments carried out in the mid-1990s at Lawrence Livermore National Laboratory (LLNL) and information presented at a British–US arms control workshop at Los Alamos National Laboratory (LANL) in 2001.

Figure 8.1 shows measurements of the gamma-ray spectrum of plutonium. The lines can be used to help distinguish (in attribute or template fashion) weapon plutonium from civil plutonium, although that distinction is not important in the weapon usability of plutonium. Nevertheless, it could prevent the substitution of civil plutonium for something that is claimed to have come from

[10] The primary is the fission explosive which is detonated first in a thermonuclear warhead containing 2 or more stages. The secondary is the warhead's fusion component.

a nuclear weapon. The energy region 635–665 kilo-electronvolts (keV) is expanded in the lower part of the curve.

Figure 8.2 is a simple illustration of the external observation via neutron counting of a sphere and a flat disc of plutonium. The two are easily distinguished.

Table 8.1 shows the regions used in a template approach with a high-resolution germanium detector in order to verify that a given item really is the nuclear device it is claimed to be.

In table 8.2, the templates are arrayed in the first row, with 'Px' one of eight pits, the five 'Fx' fully functional warheads of different types and the two 'Sx' being two secondaries in their canisters. The first column indicates the actual source presented to the counting system. All templates and sources were in a standard 'AL-R8' container, while PA* was inside a shipping container. The 'goodness of fit' of the measurement versus the templates is shown in the cells of the table. A goodness of fit below 2 is observed only when a particular source is compared with the proper template (with the exception of PC and PD, which are almost identical and hence indistinguishable by this technique).

Since a template measurement system with an information barrier (TMS/IB) could simply cause a red light to flash if the claimed TLI was not one of the claimed class, and a green light to flash if it was, no secret information could be legitimately obtained in the process. Nevertheless, the inspected party would want to ensure that detailed clandestine measurements were not being taken, and for this reason the measuring instrument is assumed to remain with the inspected party. However, the inspecting party has much greater concerns. The first concern is that the green light will not automatically flash after a 'counting interval', whatever the content of the container. Second, if the TMS/IB is truly making measurements of the claimed TLI, how can there be full assurance that the template has not been changed to agree with what the TLI actually is?

The approach would require joint preparation of templates in a 'trusted system' that is fully understood by both sides and chosen among several available for the task. The result would be a template prepared either from a 'golden warhead' (an analogy with the 'golden chip' for automated inspection of semiconductor products) or as an average of several warheads claimed to be identical and, when measured by the TMS/IB in a cooperative fashion, found to have similar characteristics. Again, the SHA-1 comes into play in assuring the inspecting party that the template which remains in the possession of the inspected party has not changed.

The measurements described above can be supplemented by data on heat, container weight and other parameters.

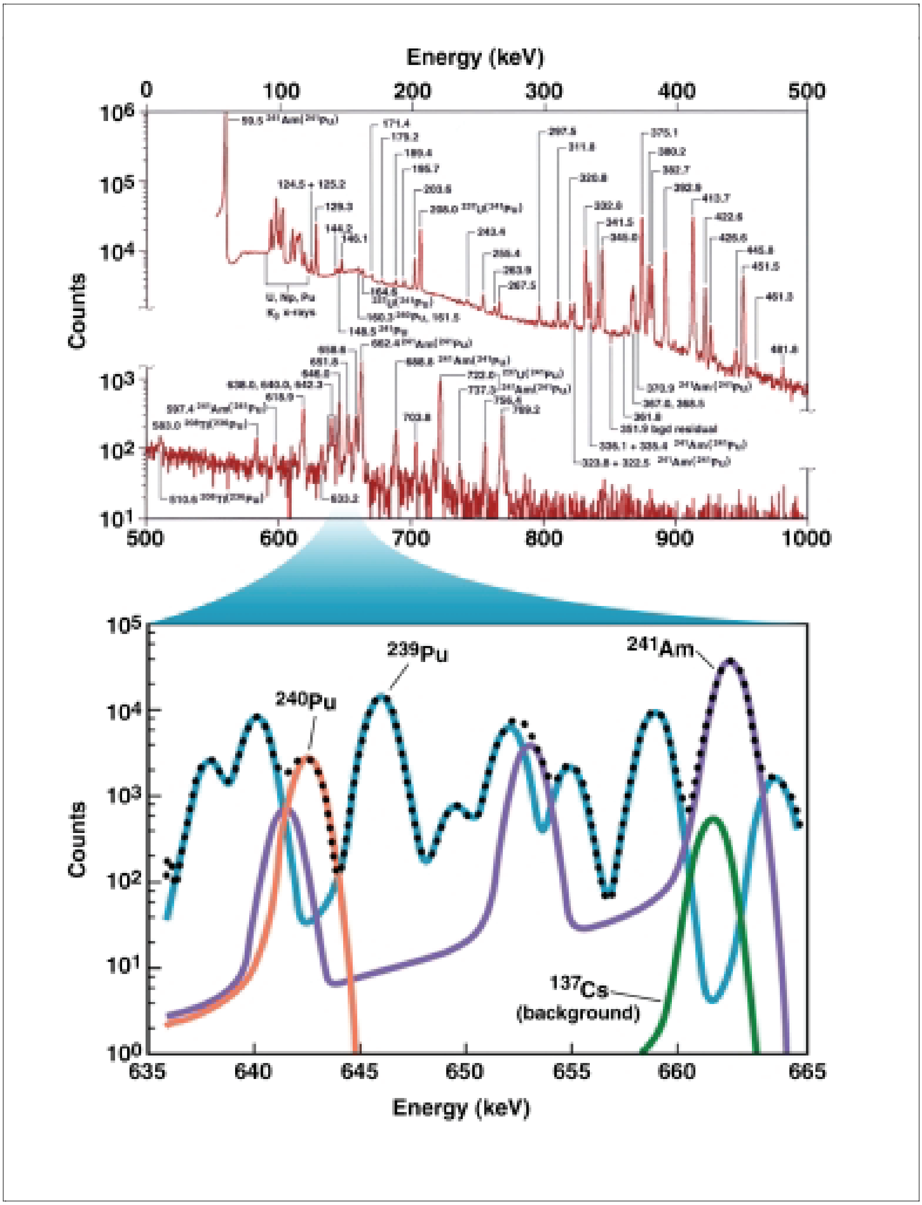

Figure 8.1. Measurements of the gamma-ray spectrum of plutonium

In the lower panel, the most complex curve is due to Pu-239, the left single-peak curve to Pu-240, the right single-peak curve to Cs-137 contamination of the site, and the 3-humped curve to Am-241, which is a decay product of Pu-241. Pu-239 is detected from the peaks at 345, 646 and 659 keV. The dots are the experimental counts vs. energy, which can be decomposed to determine relative amounts of Pu-239 and Pu-240—hence the weapon-grade quality of Pu.

Source: Gosnell, T. B., Data from Russian–US joint experiments in the mid-1990s, Lawrence Livermore National Laboratory, Livermore, Calif.

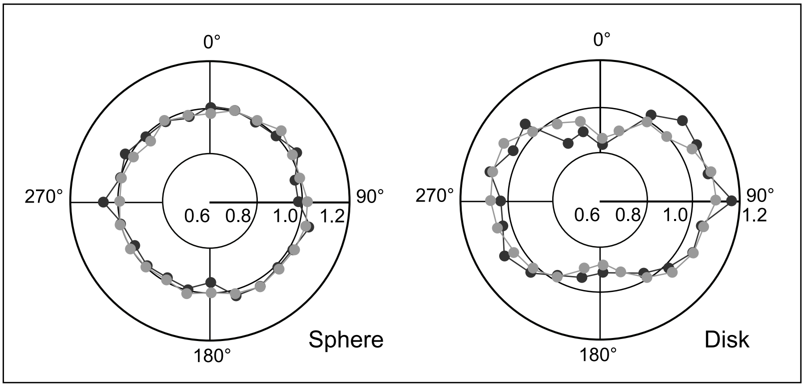

Figure 8.2. Cylindrical symmetry as indicated by an isotropic neutron radiation field

Note: Ideally, if the item is cylindrically symmetrical, the neutron counts in all detectors will be equal. A test is made for a significant variation from equality according to the formula:

$$s = \max\left(\frac{|y_i - \bar{y}|}{\bar{y}}\right), \quad \sigma_s = \frac{\sqrt{y_i}}{\bar{y}}$$

To fail the symmetry test, both s and σ_s must be large (>0.15 and >3).

Source: Gosnell, T. B., Data from Russian–US joint experiments in the mid-1990s, Lawrence Livermore National Laboratory, Livermore, Calif.

V. Warhead dismantlement

Work on warhead dismantlement carried out in the USA, and presumably also in Russia and the UK, reveals that there is a tension between assurance that a warhead has been dismantled and the fissile material properly conserved and entered into the appropriate MPC&A system, on the one hand, and the protection of nuclear secrets, thus preventing other states from improving their warhead designs, on the other hand. In the late 1960s, the Arms Control and Disarmament Agency, the Atomic Energy Commission and the Department of Defense carried out experiments on the verifiability of warhead dismantlement under the US Project Cloud Gap. The experiments monitored about 40 warheads undergoing scheduled disassembly, together with 32 objects that were not warheads. Since the inspectors were US personnel with security clearances, no effort was made to hide classified information, although the report suggested that such information could have been concealed.[11]

These experiments show that a chain of custody can be used for the warhead in its container or the warhead can be brought with its tag and appropriate seal to the portal of a relatively small and fully inspectable building where dismantling is to take place. After this, the fissile material can be placed in an MPC&A system.

[11] Arms Control and Disarmament Agency (ACDA), *Final Report—vol. 1, Field Test FT-34: Demonstrated Destruction of Nuclear Weapons* (Jan. 1969, released with deletions under the Freedom of Information Act). See also von Hippel, F., 'The 1969 ACDA study on warhead dismantlement', *Science & Global Security*, vol. 2, no. 1 (1990), pp. 103–108.

Table 8.1. Energy group structure used to analyse low-resolution spectral data

Energy range (keV)	Principal significance of the energy group	Template uncertainty (%)
80–120	U and Pu x-rays	10
120–160	Continuum	1
160–172	Sensitivity to energy-calibration error	Exclude
172–198	U-235 at 186 keV	1
198–230	U-237 at 208 keV, variable in Pu	Exclude
230–290	Continuum	1
290–350 plus 390–500	Pu-239 full-energy peak region (change in sum of counts is insensitive to energy calibration error)	1
350–390	Pu-239 full-energy peak region	1
500–600	Continuum	10
600–711	Am-241 at 662 keV, variable in Pu	20
711–821	U-238 at 766 keV	2
821–936	Continuum	20
936–1090	U-238 at 1001 keV	1
1090–1200	Continuum	5
1200–2480	Continuum from U-238 and U-232	20
2480–2750	U-232 at 2614 keV, variable in HEU	30

Am = americium; HEU = highly enriched uranium; keV = kilo-electronvolt; Pu = plutonium; U = uranium.

Source: Mitchell, D. J. (Sandia National Laboratories), Table presented at the British–US Arms Control Workshop, Los Alamos National Laboratory, Los Alamos, N. Mex., 20–21 Feb. 2001.

In principle, then, a steady stream of warheads will be coming in to the facility, and tagged and sealed fissile material will be coming out. The inspectors' concern will be that material might be accumulated inside the facility for later use in making more efficient warheads or that it would be sold or concealed. Another concern might be that fissile material (or warheads that have not been dismantled) would emerge and unbalance the residual forces. Workers, equipment, safeguarded fissile material, high explosives and non-fissile material residue from warhead dismantlement would be coming out of the facility. Some of this material might be valuable, and it is assumed that an agreement would stipulate whether it was to be crushed and rendered useless except as scrap or whether it could be retained for some other purpose. Thresholds would need to be set for monitoring the streams that are not fissile material in order to set a limit on the amount of fissile material that might escape in this way.

Periodically, work in the facility should stop at the point where all fissile material is in the form of warheads which either still bear their tags or seals or have been transferred to a container with the tags and seals. A visiting team could then inspect the facility, which should be constructed in such a manner that fissile material could not be secretly accumulated. Inspectors would be permitted to use radiation-detection equipment since there would be no warheads or fissile material to be found, except a relatively small number or amount that could be moved from a room where they might be stored to a room that had already been 'swept' and found to be clean of fissile material. This would enable the inspectors to sweep the first room as well.

It has been argued that dismantlement facilities are also used for the assembly or re-manufacture of nuclear warheads and that it would therefore be unsuitable, or very costly, to submit them to inspection in this way. Indeed, the larger the facility, the more time and effort would be lost in an inspection. Production facilities might need considerably more precise and more revealing jigs and fixtures than a disassembly system. Moreover, existing facilities might have various kinds of ventilation ducts, passages and so on that would need to be sealed or safeguarded in an inspection regime. It would therefore be preferable to build a minimal new facility rather than incurring the delay, uncertainty and cost of inspecting an existing facility.

VI. Expeditious disabling of warheads

Most nuclear warheads contain some power source, such as a lithium battery or a thermal battery. Many contain reservoirs for deuterium and tritium, for boosting the fission reactions. Under some circumstances, such components can be readily removed in the field, because they may have a limited life and are designed for such exchange, but a warhead could be restored simply by replacing the missing element.

A more permanent method for disabling a nuclear warhead—'pit-stuffing'—was introduced by Matthew Bunn.[12] US nuclear weapons could be disabled in this way because they have hollow-boosted plutonium primaries (pits) consisting of a hollow, thin shell of plutonium inside an inert metal shell, surrounded by high-explosive components. A small fill tube allows boost gas consisting of deuterium and tritium to enter the pit shortly before the warhead is fired. The warhead can be disabled and prevented from releasing any nuclear yield (not just prevented from boosting) by filling the pit with bits of metal wire that are deformed in such a way that they cannot be removed via the fill tube. If the high-explosive system were detonated, the inward moving plutonium would encounter the metal fill and never become critical. While this method will work for US warheads, it needs to be evaluated by Russian and other experts for their own nuclear warheads, which may have a different structure.

The present author has noted that the work involved in pit-stuffing needs to be addressed, the degree of irreversibility established and the importance of verification emphasized.[13] Suggestions were made as to approaches which

[12] Bunn, M., '"Pit-stuffing": how to disable thousands of warheads and easily verify their dismantlement', *FAS Public Interest Report,* vol. 51, no. 2 (Mar./Apr. 1998), available at URL <http://www.fas.org/faspir/pir0498.htm>.

[13] Garwin, R. L., 'Comment on Matt Bunn's "pit-stuffing" proposal', *FAS Public Interest Report,* vol. 51, no. 2 (Mar./Apr. 1998), available at URL <http://www.fas.org/faspir/pir0498.htm>.

Table 8.2. The average χ_m^2 for comparisons of measurements with empirical templates

		Template															
Source[a]	No.	Back	PA	PA[a]	PB	PC	PD	PE	PF	PG	FB	FC	FD	FE	FF	SB	SF
PA	1	1285	**.6**	30	86	102	98	89	140	98	1039	75	414	680	782	5223	789
PA	2	1247	**1.7**	26	78	101	96	86	136	97	940	69	378	635	766	4565	765
PA	3	1298	**1.3**	31	85	97	92	86	141	92	1057	75	436	702	814	5056	817
PA	4	1320	**.9**	34	93	105	100	92	143	100	1123	84	457	728	817	5544	827
PA[a]	1	1034	47	**.7**	61	120	118	83	130	111	572	25	180	394	560	3391	547
PA[a]	2	1021	42	**1.1**	60	122	119	83	124	112	550	29	169	375	536	3417	524
PA[a]	3	1030	43	**.9**	65	120	118	87	135	111	569	25	171	379	533	3594	524
PB	1	1009	121	107	**1.2**	93	91	15	27	81	558	91	319	547	794	1380	760
PB	2	1008	117	101	**1.0**	95	93	14	25	84	548	86	304	528	771	1427	740
PB	3	1000	119	103	**1.0**	95	93	14	25	83	542	88	305	526	770	1364	739
PB	4	996	117	101	**.9**	95	93	15	25	83	541	89	305	528	772	1361	740
PC	1	2023	497	740	698	**.7**	**1.0**	263	398	7.8	2126	808	1777	1762	1860	4010	1846
PD	1	2016	496	733	681	**1.2**	**.8**	253	385	5.8	2112	794	1763	1755	1857	3985	1842
PE	1	1328	179	195	32	84	82	**.8**	25	70	923	177	605	863	1108	1994	1081
PF	1	1284	172	190	36	128	124	20	**.7**	112	858	203	566	821	1071	1836	1045
PG	1	2003	492	710	623	9.0	6.8	221	342	**.5**	1982	761	1665	1719	1862	3527	1843
FB	1	317	129	84	116	156	156	131	139	152	**.8**	92	32	7.7	42	400	27

FB	2	312	129	82	113	154	153	128	137	150	**.9**	90	31	8.2	45	381	29
FB	3	312	123	83	113	152	151	128	135	149	**.8**	91	32	8 .5	45	386	29
FC	1	973	110	29	84	123	124	99	181	115	496	**.8**	140	336	491	3102	480
FD	1	540	113	51	90	139	139	111	142	134	63	43	**.9**	34	128	1217	113
FE	1	557	157	99	145	189	188	161	183	184	11	102	26	**.6**	46	790	33
FF	1	511	211	154	205	260	257	223	227	254	55	174	86	31	**1.0**	1477	6
SB	1	123	134	112	125	142	141	130	130	140	52	118	88	64	66	**.8**	57
SB	2	118	136	113	125	142	142	130	130	140	54	118	89	66	66	**1.3**	58
SB	3	130	135	114	128	144	143	133	134	142	53	120	90	65	65	**.8**	57
SB	4	121	135	113	126	143	142	131	131	141	54	119	90	66	66	**1.5**	58
SF	1	414	189	139	181	229	227	197	199	225	27	156	77	22	6.4	861	**.5**

P = pit (A, B, C, D, E, F, G); F = fully functional warhead (B, C, D, E, F); SB = secondary in canister B; SF = secondary in canister F.

[a] Pit A is inside a shipping container (all other pits are in AL-R8 containers).

Source: Mitchell, D. J. (Sandia National Laboratory), Table presented at the British–US Arms Control Workshop, Los Alamos National Laboratory, Los Alamos, N. Mex., 20–21 Feb. 2001.

could show that the pit really is full of wire, for example, by incorporating micro-curie quantities of cobalt-60 in the stuffing wire. One set of gamma-ray counters aligned to view the pit from one side would thus give some counts in coincidence with another gamma-ray telescope viewing it in a perpendicular direction, because cobalt-60 gives two simultaneous high-energy gamma rays. This could not be mimicked by gamma-ray sources that are not in the interior of the pit. It would be essential to ensure that cobalt-60 was present only in the stuffing wire; otherwise, a tiny amount of cobalt-60 could be inserted into the pit without sufficient inert material to disable the weapon. Because pit-stuffing depends on certain details of warhead design and fabrication, it is not an approach that can be prescribed blindly.

VII. Conclusions

Appropriate tags and seals on warheads can help solve the problem of verifying warhead dismantlement and other undertakings as well as stocks of weapon-grade fissile material.

The use of a Secure Hash Algorithm would enable information on the identity and location of each TLI to be stored in tables. A digest could be given to the other side or to the international community without any risk of revealing secret information. Later, the appropriate line could be revealed and validated by using the SHA to provide a digest that should match the secure hash that had been deposited previously.

Warhead dismantlement should take place in specially built facilities to facilitate inspections, in the form of occasional visits, to establish that fissile material has not been diverted or retained.

Finally, the disabling of warheads would benefit from further thought and ingenuity, so that irreversible reductions could be achieved before warheads are dismantled.

Appendix 8A. Russian and US technology development in support of nuclear warhead and material transparency initiatives

Oleg Bukharin

I. Introduction

Russia and the United States have planned, negotiated or implemented agreements that require nuclear warhead and fissile material verification and transparency arrangements. The nuclear transparency agenda facilitated an active research and development (R&D) effort to develop and test verification concepts and technologies. The significance of technological solutions to complex transparency problems increased further in the late 1990s, as it became apparent that the two states were not prepared to exchange classified technical information.

The USA has been particularly proactive in pursuing transparency initiatives and has taken the lead in developing the technologies. In 1999 the Department of Energy (DOE) and the Department of Defense (DOD), the two agencies primarily responsible for negotiating and implementing many of the transparency agreements, formed a Joint Steering Committee to coordinate and direct US technology development activities. The major directions of this effort include the development, integration and security evaluation of radiation measurement systems, information barriers, tamper-indicating devices and remote monitoring technologies.

The internal US technology development effort has been supported and complemented by the Russian–US Laboratory-to-Laboratory Warhead Dismantlement Transparency Program, which, as of 2001, was implemented as a part of the Warhead Safety and Security Exchange Agreement.[1] In addition, Russian technical experts have put forward innovative ideas for technologies that could be useful in future transparency applications. A cooperative development process is essential if US-proposed technologies are to be accepted by Russian technical and security experts.

[1] The 1994 Agreement on the Exchange of Technical Information in the Field of Nuclear Warhead Safety seeks to facilitate Russian–US cooperation safety, security and physical protection of nuclear weapons during transport and dismantlement. It was extended for another 5 years at the Russian–US summit meeting in 2000. See Bieniawski, A. and Irwin, P., 'Overview of the US–Russian Laboratory-to-Laboratory Warhead Dismantlement Transparency Program: a US perspective', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

The laboratory-to-laboratory programme was initiated in 1995 and has involved dozens of contracts between Russian nuclear weapon facilities and US national laboratories. Russian experts have developed and demonstrated technologies for fissile-component radiation measurements, alternative non-nuclear measurements, the detection and disposition of high explosives (HE), and the elimination of warhead casings. Russian nuclear weapon institutes have also evaluated transparency technologies developed in the USA for implementation at Russian facilities.

Russian and US technical experts have come to the conclusion that no single technology can provide a complete solution to the problems raised by transparency and that workable transparency arrangements will have to rely on a combination of technical and procedural measures. This appendix briefly describes the status of some of the key monitoring technologies which are under development or in operation in Russia and the USA.

II. Radiation measurements

All nuclear warheads contain fissile materials—plutonium and/or highly enriched uranium (HEU)—which emit gamma rays and neutrons, both spontaneously and when irradiated by neutrons from an external source. This radiation is an important nuclear warhead signature and its measurements are at the heart of the proposed transparency measures.

Templates

Radiation template (fingerprint, or radiation passport) methods were considered to be the primary candidates for use in warhead dismantlement transparency applications before 1999. They involve measurements of spontaneous and/or stimulated radiation from a nuclear warhead and its fissile material components and the use of radiation 'templates' for comparing the energy, time and correlation patterns of this radiation with reference measurements. Radiation template methods are in use at US warhead dismantlement facilities for domestic safeguards purposes, to confirm that returned warheads are intact and that random samples of warhead component containers hold specified fissile material components.

The two systems that are already operational are the Radiation Identification System (RIS) and the Nuclear Materials Identification System (NMIS). They are the most mature technically and were previously considered to be the leading candidates for warhead dismantlement transparency applications. Before 1999, Russian and US nuclear weapon laboratories also conducted R&D on several other promising systems.[2] Since then, however, active work on template

[2] One of the most technically mature systems, which was under development at the US Brookhaven National Laboratory, was the Controlled Intrusiveness Verification Technology (CIVET) system. CIVET is based on high-resolution gamma measurements, the results of which are processed by a special computer without permanent memory to prevent disclosure of classified information. The system is designed

systems has been de-emphasized and efforts have been focused on the attribute-based approach.

The RIS is a low-resolution gamma-spectrometry method currently employed at the US Pantex plant primarily for measurements on plutonium pit components. The system utilizes sodium iodide detectors and is designed to conduct a full-spectrum analysis of the low-resolution gamma spectrum. This gamma spectrum is unique for each type of warhead component because it is dependent on the amounts, shapes and types of fissile material in the measured object as well as the configuration and type of surrounding non-nuclear materials.

Data on a measured object are recorded for a few seconds by the RIS as the object is moved by the system. Multiple measurements of objects of the same type are used to select a statistically 'best' template, which serves as a reference for subsequent measurements. The system has been demonstrated to be very effective in confirming that a pit (or warhead) is of a particular type. However, the RIS cannot distinguish between two different warheads of the same type.

The NMIS, previously known as the Nuclear Weapons Identification System (NWIS), was developed at the US Y-12 plant in Oak Ridge, Tennessee, and is used at this facility to track HEU-only secondaries and warheads. It is an active interrogation system in which an object is irradiated by a californium-252 neutron source. (For tracking plutonium, which has a relatively high spontaneous neutron background, the system is capable of working in a passive mode.) The induced fission neutrons and gamma rays are then detected and correlated with themselves and each other as well as with the incident neutrons from californium-252. These correlations produce a characteristic signature for a warhead or fissile material component. NMIS has been shown to be very sensitive and capable of detecting even relatively small variations (about 4 per cent) in the amount of fissile material in the source.

Attributes

An attribute can be defined as a property of a measured object, the absence or presence of which can be determined in a Yes or No fashion without revealing quantitative information. To be useful, an attribute must be relevant, measurable and acceptable to all parties in a transparency regime. Attribute measurement techniques must also minimize the risk of the release of sensitive information.

In the past few years, radiation technology development has shifted away from template-based methods towards a focus on attribute measurements, and it has been decided to concentrate on passive radiation measurements. This shift occurred presumably because of the urgent need to agree on transparency measures to verify the weapon origin of plutonium to be placed in the Mayak

in such a way as to maximize transparency in all of its hardware and software elements. The CIVET computer, one of the initial attempts to develop an information barrier, is in principle usable in conjunction with any other measurement system to protect classified information. See also chapter 7, footnote 38, in this volume.

Table 8A.1. Attributes, thresholds and measurement approaches under the Fissile Material Transparency Technology Demonstration

		Measurement approaches	
Attribute	Threshold	Detector	Analyser/Algorithm
Presence of Pu	5σ > Bkgd at selected gamma-ray energies	HRGS (HPGe)	345 keV peaks/Pu-300 646 and 659 keV peaks/Pu-600
Isotopics	Pu-240/Pu-239 ≤ 0.1	HRGS (HPGe)	Pu-600
Pu mass	≥ 500 g	NMC	NMC Point Model and Pu-600
Absence of oxide	≤ 10% Pu oxide	HRGS (HPGe) and NMC	Pu-900 and singles from NMC
Age of Pu	Separated before 1 Jan. 1997	HRGS (HPGe)	Pu-300
Symmetry	± 15% of average counts from 8 sets of He-3 tubes in NMC	NMC	Statistical test of 8 individual counts from average of all 8 counts

Bkgd = background; He = helium; HRGS (HPGe) = High-Resolution Gamma-ray Spectrometry (High-Purity Germanium detector); NMC = Neutron Multiplicity Counter; σ = standard deviation; keV = kilo-electronvolt.

Source: Adapted from Rutherford, T. R. and McNeilly, J. H., 'Measurements on material to be stored at the Mayak fissile material storage facility', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

storage facility in Russia and because of the unresolved sensitivity issues related to templates. Moreover, the International Atomic Energy Agency (IAEA) controls on excess fissile material containing sensitive data (such as shape, mass, and chemical and/or isotopic composition) under the 1996 Trilateral Initiative[3] require a method that precludes the release of proliferation-sensitive information. Finally, the shift reflects a lack of consensus among US experts on various issues associated with the use of templates, including template initialization and storage between inspections and protection of sensitive information.

Plutonium attributes

At the August 2000 Fissile Materials Transparency Technology Demonstration (FMTTD) conducted at the Los Alamos National Laboratory (LANL), US technical experts presented the Attribute Measurement System with Information Barrier (AMS/IB) to their Russian counterparts. The presentation involved measurements on a classified plutonium pit component and reflected a generally mature concept and technology for plutonium attribute measurements.

[3] See chapters 4, 5, 10 and 11 in this volume for discussions of the IAEA–Russian–US Trilateral Initiative.

The attributes demonstrated for plutonium components are potentially applicable to transparency measures under the Trilateral Initiative and the Processing and Packaging Implementation Agreement (PPIA).[4] These attributes include: presence of plutonium, age of plutonium, plutonium isotopics, absence of plutonium oxide, and mass of the plutonium object and its symmetry (table 8A.1). It is believed that an intact plutonium pit must have all of the listed properties.

The first four attributes are determined by high-resolution gamma-ray measurements in narrow parts of the spectrum—the 330–350 keV (Pu-300), 630–670 keV (Pu-600) and 870.7 keV regions (Pu-900). The use of restricted parts of the spectrum, as opposed to the entire spectrum, minimizes the information processed and thus reduces the risk of disclosure of sensitive information. The corresponding algorithms (Pu-300, Pu-600 and Pu-900) to determine plutonium sample attributes were developed by scientists from the US Lawrence Livermore National Laboratory (LLNL) and involve peak-finding for constituent spectral lines and determination of their weighted intensities.[5]

The presence of plutonium is confirmed by the presence of peaks at characteristic energies (345 keV, 646 keV and 659 keV) if their magnitude exceeds the background radiation by a certain value. The measurements are conducted by high-resolution germanium detectors (the Canberra InSpector detector system) in the Pu-300 and Pu-600 regions.

The age of a plutonium sample (the time since the last separation of americium-241) is found by establishing the americium-241/plutonium-241 ratio. The calculation of age is based on the fact that plutonium-241 decays into americium-241 with a half-life of 13.2 years. The technique relies on gamma-spectrum measurements of americium-241, plutonium-241 and plutonium-239 peaks in the Pu-300 energy region.

The procedure for determining the isotopics of plutonium (the Pu-240/Pu-239 ratio) is similar to that used for determining the americium-241/plutonium-241 ratio. The system uses the same detector as in Pu-300 but conducts measurements in the Pu-600 region (the 646-keV peak for Pu-239 and peaks in the region of 635–642 keV for Pu-239 and Pu-240).

The technique to confirm the absence of plutonium oxide is based on the fact that all oxide samples which have been measured so far were shown to generate an 870.7 keV line (the Pu-900 region). This line arises from the decay of the first excited state of oxygen-17 and does not appear in metal samples.

The remaining two attributes—the mass and symmetry of the plutonium object—are measured by a neutron multiplicity counter (NMC).[6] (The FMTTD project utilized the 30-gallon (*c.* 114-litre) Drum NMC, which was developed by the LANL to assay plutonium components of nuclear weapons and which is routinely used by the IAEA at Rocky Flats in the USA to measure unclassified

[4] See section V of chapter 9 in this volume.

[5] Luke, S. J. and Archer, D. E., 'Gamma attribute measurements–Pu-300, Pu-600, Pu-900', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

[6] Langer, D. G. and Mayo, D. R., 'Attribute measurements using a neutron multiplicity counter', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

plutonium materials that have been declared excess and put under IAEA safeguards.) The plutonium mass is proportional to the spontaneous fission rate (measured by NMC) from a measured sample.[7] For low burn-up plutonium, the spontaneous fission rate is dominated by plutonium-240. The total sample mass can then be determined by using isotopics data from high-resolution gamma-ray measurements.

The LANL-designed NMC has a square cross-section and consists of eight slabs of polyethylene (two slabs per side), each of which contains general helium-3 detector tubes running the length of the counter's cavity. The system thus has a fourfold symmetry and can be wired to check the cylindrical symmetry of the sample.

A neutron multiplicity counter could also be suitable for determining the presence or absence of oxide in the sample. In particular, the NMC measures the rate of neutron emissions from (alpha and neutron) reactions involving oxygen, which is parameterized by the system as a ratio of the (alpha and neutron) neutron emission rate to the spontaneous fission rate. This ratio, called Alpha, is zero for pure plutonium metal and is always greater than 0.5 for plutonium oxide (for plutonium in which the ratio Pu-240/Pu-239 is less than 0.1).

HEU attributes

It is difficult to conduct passive radiation detection measurements on HEU warhead components because the gamma rays emitted by uranium-235 are very weak (U-235 produces a characteristic peak at 186 keV) and because such components are typically large, dense and inhomogeneous.[8] Even if the 186-keV line is detected, its considerable separation from the 1001-keV line for uranium-238 makes it impossible to determine uranium enrichment.[9] As of 2001, no usable HEU attribute had been developed that could be measured by passive radiation measurements.

In the absence of an HEU attribute that could be measured directly, researchers have focused on methods to detect uranium-232. Uranium-232 is produced in a nuclear reactor as a result of a complex chain of nuclear reactions and decay chains. Its decay chain includes thallium-208, which undergoes a beta-decay and emits a highly penetrating 2615-keV gamma ray.

It was reasoned that the detection of the 2615-keV thallium-208 line, in combination with the 1001-keV uranium-238 line, was a reliable indication of the presence of HEU for two reasons. First, all the US gaseous diffusion enrich-

[7] The rate is determined by using a theoretical model of fission and measured data on a total neutron emission rate, as well as the rates of doubles and triples (all of which are deduced from a spectrum of time-correlated neutron multiplicity events).

[8] Gosnell, T. B., 'Uranium measurements and attributes', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

[9] Estimating true relative emission intensities of the 2 lines in this case is difficult because of their unknown differential attenuation. This problem cannot be resolved without calibration against known standards, which is believed to be impractical in most verification scenarios.

ment plants were used to re-enrich uranium recovered from irradiated fuel from plutonium production reactors and thus became contaminated with uranium-232. All the HEU produced by these facilities therefore contains trace amounts (typically 100–200 parts per trillion) of uranium-232. It is believed that HEU in other nuclear weapon states is similarly contaminated with uranium-232.[10] Second, the enrichment process concentrates essentially all uranium-232 in the lighter HEU faction, while the heavier tails faction contains no measurable amounts of uranium-232. The presence of uranium-232 is thus a strong indicator of the presence of HEU.

Templates vis-à-vis attributes

The main thrust of technology development in the area of radiation measurements is currently on attribute measurement systems (for a comparison of attribute and template approaches see table 8A.2). There are several principal advantages of the attribute approach compared to the template approach. The use of attributes does not require a reference item and thus completely avoids the difficult problem of template initialization. With attributes, in contrast to templates, there is no need to securely store highly sensitive information. Indeed, the recording and storing of sensitive information present significant security risks. The attributes approach may thus be an easier approach to negotiate and more practical to implement in the short term under the Trilateral Initiative and the PPIA, both of which focus on fissile material and warhead components.

The attributes approach nevertheless raises several problems, particularly when applied to measurements on intact nuclear warheads or their major subassemblies. The most significant problem is establishing a meaningful quantitative value and an acceptable deviation which do not reveal sensitive design information. The attributes approach also makes it more difficult (if not impossible) to resolve an anomalous situation. Ideally, the development effort should pursue both approaches simultaneously, with the understanding that short-term transparency measures, in particular when applied to fissile material, will involve attribute measurements while future transparency in warhead dismantlement could involve template measurements.

III. Information barriers

Radiation measurements of a nuclear warhead or a classified warhead component can be intrusive and reveal sensitive information on warhead design. As

[10] It should be noted that this assumption might in fact be incorrect. A significant fraction of Russian HEU was produced by centrifuge plants. Some of the HEU production possibly took place in uncontaminated enrichment cascades and used natural uranium as a feed material. Also, centrifuge cascades could be effectively flushed to remove U-232 contaminants even if they were previously used to enrich reprocessed uranium.

Table 8A.2. Attribute and template approaches

Attributes	Templates
Characteristics of a single item evaluated	Comparison with a reference item
Information barrier required	Information barrier required
No storage of reference data	Storage of reference data required
Requires quantitative value and acceptable deviation	Quantitative value is unknown; parameter comparison is more precise

discussed above, measurements of the gamma-ray spectrum, for example, could be used to establish the isotopic composition of plutonium, a parameter which is classified by Russian law.[11] Other potentially highly sensitive information could be also deduced. According to US national laboratory experts:

[B]y coupling these [weighted intensities of measured spectral lines] with the detector efficiency and measurement geometry, one may also place a lower limit on the mass of the radiating source. (Lack of knowledge of the surface area and uncertainties in the amount of self-absorption for a concealed source keep this from being a more exact estimate.) Combining the spectral intensities with a knowledge of the decay chains of the sources present gives an estimate of the time elapsed since the sample was prepared or otherwise had some known composition. Subtler aspects of the spectrum, such as the height of continuum relative to key constituent lines, provide information about absorption and scattering due to intervening material. Knowing the relevant cross-sections and the density of likely absorbers gives one a means of bracketing the material thickness. Also, in [a] neutron-producing source such as plutonium, the presence of other significant elements can be inferred from evidence of their activation products. Clearly, the spectrum contains a wealth of information about the object being measured.[12]

Radiation measurements of sensitive objects are therefore unacceptable unless classified information is reliably protected. To meet this requirement several US national laboratories have started to develop radiation detection information barrier (IB) systems. A working model of an IB system was demonstrated to Russian technical experts as a part of the FMTTD demonstration in August 2000.

An IB system involves a combination of technology (hardware and software) and procedural elements and is designed to protect classified information from disclosure to inspectors while at the same time giving inspectors confidence in the integrity of radiation measurements and in the result.

The security function is implemented through a combination of measures including the use of: (*a*) successive data barriers between the parts of the system that handle sensitive information and input/output devices; (*b*) volatile

[11] The isotopic composition of weapon-grade plutonium produced in the USA and imported from the UK was declassified in Apr. 1964 and May 1965, respectively. See US Department of Energy (DOE), *Restricted Data Declassification Decisions 1946 to the Present,* RDD-7 (DOE: Washington, DC, 1 Jan. 2001), p. 27.

[12] Wolford, J. K., Jr and MacArthur, D. A., *Safeguards for Nuclear Material Transparency Monitoring*, UCRL-JC-134787 (Lawrence Livermore National Laboratory: Livermore, Calif., 1999), p. 5.

memory and read-only booting devices (such as CD-ROMs); (*c*) single-function Yes/No (green-light/red-light) displays; (*d*) a security 'watchdog' system that monitors the IB system and automatically shuts down the power source if insecure conditions are detected (e.g., open access hatches or software glitches); and (*e*) a shielded enclosure to prevent electronic leaks from and into the system, a technology which is implemented in conjunction with procedural measures (e.g., the use of metal detectors to prevent inspectors from bringing unauthorized electronic and other devices into measurements rooms).

Under certain circumstances, the observation of equipment set-ups and conduct of measurements could lead to a disclosure of sensitive information. This consideration calls for a design that includes automatic, intelligent operation of the measurement system (i.e., without a human operator).[13]

Another important principle for the design of an IB system is the use of trusted, inspectable hardware and software.[14] It is presumed that an IB system would be supplied by a host country. In principle, this could mean that, even when the system has been designed and built by the inspecting country, the host country will have unlimited and unrestricted access to it before it is used. Inspectors would then require assurances that the host country had not introduced hidden switches that could be used to deceive the inspection process. For a system designed and manufactured by the inspecting country, the host country would require that the equipment did not contain any clandestine devices that could be used to collect or transmit sensitive information outside of the IB.

The inspectability of the IB could be achieved by using: (*a*) trusted central processing units based on single-board dedicated computers; (*b*) inspectable X-ray detector subsystems (a high-purity germanium detector, liquid nitrogen dewar or pulse preamplifier) and electronic equipment (multi-channel analysers and power supplies); (*c*) software that could be checked line by line; and (*d*) simple, single-function input/output systems. System checks and the use of unclassified calibration sources prior to inspections would probably be adequate to ensure that the system had been assembled and functioned as designed. After such an initialization, the measurement system could be stored under a dual-key arrangement in the time between inspections.

IV. Detection of high explosives

The presence of high explosives in combination with fissile material is a strong indicator that an object is a nuclear warhead.[15] Measurements to detect high

[13] E.g., for a gamma-ray detector with known efficiency, an optimal inspection configuration (the distance between the detector and the measured object and the count rate) would provide an indication of the size of a fissile material component. In FMTTD, the solution was to conduct a measurement for a fixed count time and at a fixed distance. To maintain measurement quality, the AMS/IB system is designed to adjust the detector's solid angle automatically by regulating an adjustable tungsten iris (diaphragm).

[14] This aspect of IB technologies is discussed in Fuller, J. L. 'Information barriers', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

[15] For safety reasons, radioactive and explosive materials are kept separately in non-weapon applications.

explosives in a declared excess warhead under a transparency arrangement, or during its authentication prior to dismantlement, could therefore increase inspectors' confidence that the monitored item is indeed a warhead.

Conventional methods of detecting explosives (e.g., in access control applications at high-security facilities) rely on the collection and analysis of explosive vapours. In research conducted by scientists at the All-Russian Scientific Institute of Technical Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF) in Chelyabinsk-70, these techniques were found to be less effective when used to detect the HMX type of explosives (presumably because of their very low vapour pressure) that are used in many modern nuclear weapons.[16] Gas-analysis methods for the detection of high explosives could be particularly ineffective for detecting explosives inside a tightly sealed nuclear warhead.

Radiation methods are generally more effective for detecting explosives. They are based on the irradiation of a warhead or an HE container by neutrons from a californium-252 neutron source and detection of resulting thermal neutrons and/or gamma rays. The thermal neutron analysis method, for example, looks for 10.8-mega-electronvolt (MeV) gamma rays emitted by nitrogen as it decays from its excited state (nitrogen-15) to its ground state (nitrogen-14).[17] Nitrogen is found in all the chemical explosives used in nuclear weapons and the detection of 10.8-MeV gamma rays thus suggests the presence of high explosives.

Technical experts in the United States have proposed the use of the Portable Isotope Neutron Spectroscopy (PINS) system, which is available commercially, in warhead transparency applications.[18] Because radiation measurements would reveal classified information about fissile material components, such measurements would require the use of an IB. HE detection measurements could possibly be integrated with fissile material attribute measurements.

V. Non-nuclear measurements for nuclear warheads and materials

Non-nuclear technologies could potentially be a relatively inexpensive and non-intrusive complement to radiation measurements and other transparency technologies. As of 2001, non-nuclear technologies were in a rather early R&D stage, although much work in this area has been done under the laboratory-to-laboratory contracts between the All-Russian Scientific Institute of Experimental Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Experimentalnoy

[16] Pokatashkin, A. K. *et al.*, 'High explosive detection and destruction', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

[17] An excitation of a nitrogen atom occurs as it captures a thermal neutron.

[18] Dubinin, V. P. and Doyle, J. E., *Item Certification for Arms Reduction Agreements: Technological and Procedural Approaches,* LA-UR-00-2740 (Los Alamos National Laboratory: Los Alamos, N. Mex., 2000).

Fiziki, VNIIEF) in Arzamas-16 and the US Pacific Northwest National Laboratory (PNNL).

The non-nuclear transparency technologies under consideration include the vibro-acoustic, magneto-vibrational, thermal and chemical sensor methods.[19]

1. *Vibro-acoustic method.* Research focuses on measuring the amplitude–frequency characteristics of an AT-400 container (a fire- and shockproof container designed for the transport and storage of HEU and plutonium) in response to a mechanical input signal (vibrator-induced oscillations or a hammer stroke).

2. *Magneto-vibrational method.* With this technique, a containerized warhead or component is placed inside an inductance coil. A low-frequency magnetic flux is then induced in the coil and measurements are made of a frequency-dependent phase shift in the magnetic field. The phase-frequency characteristic represents a unique electromagnetic signature of the measured item.

3. *Thermal field registration method.* Radioactive decay and spontaneous fission processes in radioactive materials generate heat. It is believed that if a container has fissile material inside, the distribution of the temperature inside the container and on its surface, as well as the maximum container temperature relative to that of outside air, could provide a useful fingerprint.

4. *Chemical sensor method.* This technique utilizes miniature microelectronic sensors to measure physical parameters (e.g., temperature, pressure and gas composition) inside a container with fissile material to verify that the container and its contents remain in a steady-state configuration.

Non-nuclear technologies could be used in combination. Scientists at VNIIEF,[20] for example, have proposed examining the utility of the following combination of non-nuclear measurements: weight, centre of gravity, plutonium presence and mass attributes, concentration of gases (from unclassified materials), temperature at fixed points on a warhead casing or container and relative position of the nuclear assembly inside the warhead.

VI. Limited chain-of-custody technologies

In the context of warhead dismantlement transparency, the term ‘chain of custody’ means that a system of routines has been set up to provide a high level of confidence that a treaty-limited nuclear warhead will be delivered (for example, from its field deployment location) to a warhead dismantlement facility, and that recovered fissile material will be monitored until final disposition to preclude its reuse in new nuclear weapons. The chain of custody is limited because inspectors will not be able to monitor the warhead during its disassembly.

[19] The descriptions of methods are based on Smoot, J. *et al.,* ‘Non-nuclear technologies: potential application to support fissile material safety and security’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

[20] Smoot *et al.* (note 19).

Table 8A.3. Tags and seals for warhead transparency applications

Tag or seal	Technical and operating principles
INF and START I technologies	
Reflective particle tags (RPT)	Reflective particles are dispersed randomly in acrylic film which is applied to a treaty-limited item. The particle pattern is read and correlated by an optical reader.
Fibre optic seals	Several fibre optic seals have been developed, including the Cobra seal (see below), the Python seal (a combination of the Cobra seal and RPT), and the Star seal (an active fibre optic system).
Ultrasonic intrinsic tags (UIT)	UIT are based on information about the sub-surface microstructure of an item. A sample is interrogated ultrasonically and sub-surface structure data are collected by a hand-held scanner. The alignment and correlation functions are performed by a computer. UIT are highly resistant to counterfeit and surface changes.
Electronic identification devices	This tag was developed for START I applications. It features special electronic circuits, which are mounted on a capacitance probe.
Surface feature tags	These tags create a unique fingerprint of an item by examining its surface. Examination techniques include holographic interferometry, scanning electron microscopy and micro-videography.
Shrink-wrap seals	Shrink-wrap seals consist of a plastic film which shrinks tightly around the safeguarded item. Multiple layers of geometrically patterned film produce a unique pattern that can be photographed for verification purposes.
O*ff-the-shelf commercial systems*	
E-type cup wire loop seals	This seal, which is widely used by the IAEA, consists of two metal cups that snap together covering the crimped ends of a wire loop. The insides of the cups are covered with melted solder and scratched to create a unique pattern. The pattern is recorded for future comparison.
VACOSS fibre optic seals	This seal includes a loop of fibre optic cable, which is actively interrogated by the seal's electronic system for integrity. The seal can be read remotely. The IAEA uses VACOSS seals to monitor plutonium at Hanford.
Cobra seals	The Cobra seal consists of a polycarbonate sealing body and a loop of a fibre optic cable. A blade cuts the cable, creating a unique light pattern that is recorded photographically by the Cobra Seal reader and used for future comparison.

Tag or seal	Technical and operating principles
Pressure-sensitive adhesive seals	Adhesive seals consist of fragile labels and are attached to an item by using pressure-sensitive adhesives. Some seals include microscopic glass beads that create a unique reflective patterns. These seals typically do not provide the same high level of security and are often used for short-term applications.
E-tag mechanical seals	The seal is similar to the E-type cup seal but it also includes an electronic chip. It contains a unique identification number, which can be verified without opening the seal.
T-1 radio-frequency seals and tags	Designed at Sandia National Laboratories, this system includes a fibre optic seal, motion detector, case tamper switches, and high and low temperature indicators.
Seals and tags under development	
Acoustic tags	Acoustic tags are based on the unique resonant acoustic properties of an item when interrogated by sound waves of specific frequencies.
Radio-frequency (RF) tags	RF tags emit a unique identification number when interrogated by an external RF device.
Ultrasonic intrinsic tags: improved version	An improved version of the UIT has been developed for INF/START applications.
VNIIEF smart bolts	The smart bolt seal is designed for application on AT-400R fissile material storage containers. Single-use and multiple-use versions of the seal are under development. A digital identification and unique electrical properties are read from the seal by a small reader. Unscrewing the bolt changes its electrical properties and indicates tampering.
VNIITF OPP-1M and ZP-1 seals	The OPP-1M seal is a multi-purpose optical loop seal that uses a unique pattern created by wire filaments inside the seal's body. The ZP-1 seal is similar to the OPP-1M seal but is configured as a locking bolt for application on storage containers.

INF = 1987 Soviet/Russian–US Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty); START I = 1991 Russian–US Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I Treaty); VACOSS = Variable Coded Safeguards Sealing System; VNIIEF = All-Russian Scientific Institute of Experimental Physics; VNIITF = All-Russian Scientific Institute of Technical Physics.

Source: Based on Rubanenko, N. *et al.*, 'Tags and seals in a transparency regime', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

There are a range of technical and procedural approaches to maintaining a chain of custody. The most reliable method would be to maintain a warhead under continuous visual observation by an inspector until it is delivered to a dismantlement facility, but this method is impractical in most scenarios. Inspector confidence could be increased by checks of related documentation such as shipper–receiver forms and dismantlement records. However, the primary method of maintaining a limited chain-of-custody of warheads and fissile materials would probably be the use of tamper-indicating devices (TIDs), such as tags and seals.[21] Inspector visits, possibly complemented by continuous remote monitoring of stored warheads (prior to dismantlement) or fissile material would be another key limited chain-of-custody element.

Tags and seals

Tamper-indicating devices would be used to provide assurance that a monitored nuclear warhead or fissile material container has not been substituted or tampered with. Tags and seals would also be essential to provide indications of tampering with data and equipment during and between inspections, as well as to secure other safeguards elements of a transparency regime such as surveillance cameras and recording equipment.

Tags and seals have been employed extensively for domestic safeguards and international verification purposes. A wide range of tags and seals have been developed specifically for arms control applications or are available commercially (table 8A.3). However, according to experts at the Los Alamos National Laboratory,

> most tags and seals are highly vulnerable to tampering when they are not being monitored. In one study, every seal tested was defeated within five minutes (if the seal was not under some form of monitoring). This study demonstrated that without careful considerations as to selection of which tags and seals to use, the establishment of procedures for their application, removal and autopsy, and monitoring of seals between application and removal, tags and seals may be of limited value in maintaining the chain-of-custody of an item.[22]

Consequently, a greater emphasis has recently been placed on vulnerability assessment tests of various tag and seal systems. Some US national laboratory experts have also proposed a new configuration, called 'dynamic monitoring technology', in which a TID is constantly monitored by a miniature, tamper-protected surveillance camera.[23] However, there are many applications in which several of the more traditional TIDs or devices under development, when used carefully and properly, could also provide adequate indication of tampering.

[21] According to Roger Johnston, an LANL expert on tamper-indicating devices, 'Tags are applied or intrinsic features or devices used to identify an object or container. . . . Seals are tamper-indicating devices (TIDs) meant to detect unauthorized access to a door, container, or package'. Johnston, R. G., 'Tamper detection for safeguards and treaty monitoring: fantasies, realities, and potentials', *Nonproliferation Review*, vol. 8, no. 1 (spring 2001), p. 102.

[22] Olinger, C. *et al.*, 'Technical challenges for dismantlement verification', *Proceedings of the 38th Annual Meeting of the Institute for Nuclear Materials Management (1997)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

[23] Gerdes, E. R., Johnston, R. G. and Doyle, J. E., *A Proposed Approach for Monitoring Nuclear Warhead Dismantlement*, LA-UR-00-2222 (Los Alamos National Laboratory: Los Alamos, N. Mex., 2000), p. 30.

VII. Remote monitoring

Remote monitoring could be a cost-effective complement to inspection visits to nuclear warhead or fissile material storage facilities. As part of the Russian–US laboratory-to-laboratory programme, VNIIEF and the Sandia National Laboratories (SNL) have been working cooperatively to develop advanced remote monitoring technologies.[24]

The first (container-to-container) stage of this cooperation involved the collection of data from container-monitoring devices. The data were made available on the Internet. During the second (magazine-to-magazine) stage, the project was expanded to simulated storage magazines (rooms at VNIIEF and SNL with mock-up containers with fissile material). The magazine-to-magazine demonstration involved the use of access control devices for the rooms and containers and an Internet data-sharing arrangement for monitoring the status of the sensors over a long period of time.

The third and final (facility-to-facility) stage of the project was planned for implementation in 2001 and was to involve stand-alone storage facilities in Russia and the USA. The USA provided the slug (fuel element) vault at the K-Reactor Basin of the DOE Savannah River site. The vault was to accommodate significant quantities of HEU. The Russian facility was to be located on the VNIIEF site. Each facility would be equipped with a similar set of equipment, including: (*a*) radio-frequency tamper-indicating devices with fibre optic loops on fissile material containers to monitor container closure; (*b*) motion detectors (passive infrared and video detectors) in the room; (*c*) door sensors (balanced magnetic switches and break-beam sensors); and (*d*) surveillance still-frame cameras to be activated by motion sensors. Sensor output would be directed to a data collection computer, which would forward it to a data storage computer. The latter would have an Internet information server that would present data to users in a standard Web browser interface. The system would be capable of data encryption and authentication.

VIII. Disposition of non-nuclear components

Monitored destruction of the key non-nuclear components of a nuclear warhead—its high-explosive components and ballistic casing—could provide an additional level of confidence in the irreversibility of warhead elimination. In itself, however, this measure would not be sufficient because the host country could manufacture additional components or maintain a large stock of spare components. Under the laboratory-to-laboratory programme, Russian technical experts explored and demonstrated hydro-jet cutting technologies for non-nuclear components. Because the shapes of the components are classified information, the destruction process takes place behind a shroud. The fact of

[24] Lockner, T. *et al.,* 'Progress towards complementary cooperative monitoring facilities at the Savannah River site, USA and VNIIEF, RF', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 1).

destruction is confirmed by placing a ‘transparency’ cutting plate behind the component. The jet cuts through both the component and the plate, and the remains of the latter are presented to inspectors for examination. Because of safety concerns, destruction of HE is carried out remotely and is monitored via television cameras.

IX. Conclusions

Russian and US technical experts are working to develop technologies and procedures for nuclear warhead dismantlement and material transparency. Significant progress has been made in several technology areas, including radiation measurements, information protection, chain-of-custody measures, remote monitoring and disposition of non-nuclear components.

The technology base for warhead dismantlement transparency is far from complete, however. Additional advances must be made, for example, in the areas of HEU measurements and HE detection. Further development of template measurement technologies and procedures is also required to eventually complement or replace attribute-based approaches for nuclear warheads and major sub-assemblies.

Significant work is needed to integrate individual technologies and to develop detailed implementation protocols for specific nuclear weapon programmes and facilities. Transparency technologies and procedures must also be thoroughly evaluated to ensure that the safety of the dismantlement process is not compromised, that costs and impacts on facility operations are minimized, and that sensitive nuclear weapon information is reliably protected.

9. The changing Russian and US nuclear weapon complexes: challenges for transparency

Oleg Bukharin

I. Introduction

Russian and US technical experts are working to develop technological and procedural approaches to the monitoring of nuclear warhead dismantlement in the event that Russia and the United States reach an agreement calling for such a transparency regime. In order to be negotiated and implemented at nuclear weapon facilities, a transparency regime must be designed to have minimal impact on facility operations and the financial burden of inspections as well as to protect sensitive nuclear weapon information. Furthermore, a regime must take into account the considerable differences that exist between Russia and the USA in the structure and organization of their nuclear warhead production complexes and operations.

Sections II and III of this chapter present an overview of the post-cold war warhead production complexes of the Russian Ministry of Atomic Energy (Minatom) and the US Department of Energy (DOE) and briefly describe their warhead dismantlement processes. Sections IV–VI address some of the operational, technical, political and perceptional problems of implementing warhead dismantlement transparency in Russia and the USA and outline steps that could be taken by the two states.

II. Russia's nuclear weapon complex and warhead dismantlement operations

Minatom's warhead production complex comprises 17 research institutes and production facilities (table 9.1). Six facilities participate in warhead dismantlement operations directly. The dismantlement of intact warheads and, possibly, nuclear explosive packages (NEPs) takes place at four 'serial production' assembly–disassembly facilities located in the closed nuclear cities of Arzamas-16, Sverdlovsk-45, Zlatoust-36 and Penza-19.[1] The fissile material processing complexes in Chelyabinsk-65 and Tomsk-7, where the manufacturing of fissile material warhead components takes place, are involved in the

[1] Since 1992, these cities have had new official names (table 9.1), although the cities and their facilities are still referred to by their former names.

Table 9.1. The Russian Minatom nuclear warhead production complex, 2001

Facility English (Russian) name	Location (old name if applicable)	Nuclear warhead production functions
Institute of Experimental Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Experimentalnoy Fiziki, VNIIEF)	Sarov (Arzamas-16)	Nuclear warhead design Stockpile support
Institute of Technical Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF)	Snezhinsk (Chelyabinsk-70)	Nuclear warhead design Stockpile support
Institute of Automatics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Avtomatiki, VNIIA)	Moscow	Nuclear warhead design and engineering Design of non-nuclear components Nuclear weapon maintenance instrumentation
Institute of Impulse Technologies (Vserossiyskiy Nauchno-Issledovatelskiy Institut Impulsnoy Tekhiki, VNII IT)	Moscow	Nuclear test diagnostics
Institute of Measurement Systems (Nauchno-Issledovatelskiy Institut Izmeritelnykh Sistem, NII IS)	Nizhni Novgorod	Design of non-nuclear components
Design Bureau of Road Equipment (Konstruktorskoye Buro Avto-transportnogo Oborudovaniya, KB ATO)	Mytischy, Moscow region	Nuclear warhead transportation and handling equipment
Siberian Chemical Combine (Sibirskiy Khimicheskiy Kombinat, SKhK)	Seversk (Tomsk-7)	Fabrication of HEU and plutonium weapon components
Production Association 'Mayak' (Proizvodstvennoye Obyedinenie 'Mayak')	Ozersk (Chelyabinsk-65)	Production of tritium and tritium components of nuclear warheads Fabrication of HEU and plutonium weapon components
Mining and Chemical Combine (Gorno-Khimicheskiy Kombinat, GKhK)	Zheleznogorsk (Krasnoyarsk-26)	Plutonium management
Electrokhimpribor (Kombinat Elektrochimpribor)	Lesnoy (Sverdlovsk-45)	Nuclear warhead assembly–disassembly
Electromechanical Plant 'Avangard' (Elektromechanicheskiy Zavod 'Avangard')	Sarov (Arzamas-16)	Nuclear warhead disassembly
Production Association 'Start' (Proizvodstvennoye Obyedinenie 'Start')	Zarechny (Penza-19)	Nuclear warhead disassembly
Device-Building Plant (Priboro-Storitelnyiy Zavod)	Trekhgorny (Zlatoust-36)	Nuclear warhead assembly–disassembly

Facility English (Russian) name	Location (old name if applicable)	Nuclear warhead production functions
Production Association ‘Sever’ (Proizvodstvennoye Obyedinenie ‘Sever’)	Novosibirsk	Production of non-nuclear weapon components
Production Association ‘Molnia’ (Proizvodstvennoye Obyedinenie ‘Molnia’)	Moscow	Production of non-nuclear weapon components
Urals Electromechanical Plant (Uralskiy Electromechanicheskiy Zavod)	Yekaterinburg	Production of non-nuclear weapon components
Nizhneturinskiy Mechanical Plant (Nizhneturinskiy Mechanicheskiy Zavod)	Nizhnyaya Tura	Production of non-nuclear weapon components and support equipment

Sources: Podvig, P. (ed.), *Russian Strategic Nuclear Forces* (MIT Press: Cambridge, Mass., 2001); and Bukharin, O., von Hippel, F. and Weiner, S., *Conversion and Job Creation in Russia’s Closed Nuclear Cities* (Program on Nuclear Policy Alternatives, Princeton University: Princeton, N.J., Nov. 2000). This table also appears in Bukharin, O., ‘The changing Russian and US nuclear warhead production complexes’, *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 588–89.

management, storage and disposition of highly enriched uranium (HEU) and plutonium components. Lithium-6 deuteride thermonuclear fuel is shipped for storage to the Novosibirsk Chemical Concentrates Plant in Siberia.

The four Russian serial production facilities are highly secretive, and little information is available about their specific functions. One report, for example, suggests that only the Arzamas-16 and Sverdlovsk-45 plants manufacture, refurbish and dismantle NEPs.[2] The Russian plants presumably specialize in the types of warhead they produce and eliminate. For example, the Avangard plant in Arzamas-16 has in recent years worked primarily on warheads designed by the All-Russian Scientific Research Institute of Automatics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Avtomatiki, VNIIA) in Moscow for the Russian Navy and Air Force.[3]

In addition to the four largest serial production plants, the All-Russian Scientific Research Institute of Technical Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF) in Chelyabinsk-70 and the All-Russian Scientific Research Institute of Experimental Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Experimentalnoy Fiziki, VNIIEF) in Arzamas-16 each have pilot plants that can manufacture nuclear warhead components and assemble prototype and experimental nuclear warheads.[4]

[2] Sutyagin, I., [‘Problems of safety and security of Russian nuclear weapons’], *Voenny Vestnik*, no. 7 (1993), pp. 62–76 (in Russian).

[3] Zavalishin, Yu., [‘Avangard’ Atomic] (Krasny Oktyabr’: Saransk, 1999), p. 86 (in Russian).

[4] Koblov, P. *et al.* (eds), [Russian Federal Nuclear Center—All-Russian Scientific Institute of Technical Physics] (VNIITF: Snezhinsk, 1998), p. 16 (in Russian).

The Russian nuclear weapon complex is in the process of being downsized and restructured.[5] Warhead assembly is no longer conducted at the Avangard plant or at the Start complex in Penza-19. As of 2001, the Russian Government's plan was to phase out warhead disassembly at these two facilities by 2003, presumably when the warheads they produced in the past have been dismantled. Given this closure schedule, the Avangard and Start plants are unlikely to be involved in future warhead dismantlement transparency arrangements. The plutonium and HEU component manufacturing facility in Tomsk-7 has reportedly stopped weapon production work. Significant consolidation has taken place at facilities that manufacture mechanical, electronic and other non-nuclear components for nuclear warheads. Finally, the pilot plants at the nuclear warhead design institutes of VNIIEF, VNIITF and VNIIA are responsible for the production of certain components and assemblies that were previously manufactured by serial production facilities.

Minatom officials estimate that the planned complex reductions could be completed in 10–12 years with the funding that is expected to come from the Russian Government, or in 5–7 years if significant international assistance is provided. Domestic political factors and arms control developments could also affect the pace of complex downsizing.

Although the planned reductions are ambitious, they may result in a nuclear weapon complex that is still oversized relative to Russia's future nuclear defence needs and economic capabilities.[6] Further reductions in the warhead production infrastructure could therefore be expected in the future.[7] For example, all the warhead re-manufacturing and surveillance operations could be consolidated at one facility, most likely in Sverdlovsk-45. Deep cuts, in the longer term down to hundreds of warheads, in the nuclear arsenals of the five nuclear weapon states recognized under the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT) would make it possible to further consolidate all the Russian warhead production and maintenance activities in the warhead design institutes in Arzamas-16 and Chelyabinsk-70. In that case, Sverdlovsk-45 would focus on warhead dismantlement and then be adapted for civilian purposes.

Warhead dismantlement

There is little open information about the processes of warhead retirement and dismantlement in Russia. The following description is based on both available

[5] This discussion is based on a presentation by Minatom's First Deputy Minister Lev Ryabev at the International Conference on Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities, Princeton University, Princeton, N.J., 14–15 Mar. 2000.

[6] Minatom is currently working on a new complex restructuring plan for steps to be taken up to 2010, which has not yet been made public.

[7] For an analysis of the downsizing options for the Russian complex see Bukharin, O., *Downsizing of Russia's Nuclear Warhead Production Infrastructure*, PU/CEES Report no. 323 (Princeton University, Center for Energy and Environmental Studies (PU/CEES): Princeton, N.J., May 2000); and Bukharin, O., 'The changing Russian and US nuclear warhead production complexes', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 585–97.

data and unconfirmed assumptions and represents a plausible hypothetical scenario of the Russian warhead dismantlement process (figure 9.1).

After a retirement decision is made, nuclear warheads are separated from their delivery systems by officers of the corresponding military service and placed inside storage and transportation containers. At this point, the custody of the retired warheads is transferred to officers of the Russian Ministry of Defence (MOD), 12th Main Directorate, an organization which is responsible for managing nuclear warheads that are not associated with delivery systems and for interfacing with Minatom's warhead production complex. A batch of retired warheads is then shipped, usually by rail, to a central warhead storage facility—either a stand-alone installation or one associated with a warhead dismantlement plant. (Large MOD warhead storage complexes exist near the dismantlement plants in Sverdlovsk-45 and Zlatoust-36.[8]) According to a dismantlement schedule, retired warheads are delivered to the originating serial assembly–disassembly plant. In some cases, warheads may be shipped directly to an assembly–disassembly plant, where they are stored in the plant's staging area prior to their dismantlement.

According to Yuriy Zavalishin, a former director of the Avangard plant, after a container containing a warhead is received at a warhead disassembly plant, the facility's operators, in the presence of representatives from the MOD and the corresponding warhead design institute, open the container, conduct entry radiological control of warhead surfaces and verify documentation.[9] A dismantlement authorization decision is then made and the warhead enters the disassembly process.

Warhead disassembly takes place in specialized concrete cells. The dismantlement process includes the following steps: (*a*) separation of the NEP from the warhead; (*b*) removal of the primary from the physics package; (*c*) separation of fissile materials from the primary and the secondary; (*d*) packaging and temporary storage of fissile materials; and (*e*) mechanical disassembly of non-nuclear parts. High-explosive (HE) components are burned. Non-nuclear components that were in direct contact with fissile materials are cemented inside containers and are disposed of on-site at fenced-off waste storage areas. Other non-nuclear components are sanitized (e.g., ballistic casings are deformed) and then recycled or disposed of.

The dismantlement process may differ from one plant to another and from one type of warhead to another. For example, the initial mechanical disassembly and NEP removal operations for intercontinental ballistic missile (ICBM) and submarine-launched ballistic missile (SLBM) warheads of certain types may take place at the Zlatoust-36 facility. NEPs may then be shipped for further disassembly to the serial production complex in Sverdlovsk-45. The disassembly of secondaries may also take place in Sverdlovsk-45.

[8] Handler, J. 'Lifting the lid on Russia's nuclear weapon storage', *Jane's Intelligence Review*, Aug. 1999, pp. 19–23.

[9] Zavalishin (note 3), pp. 272–80.

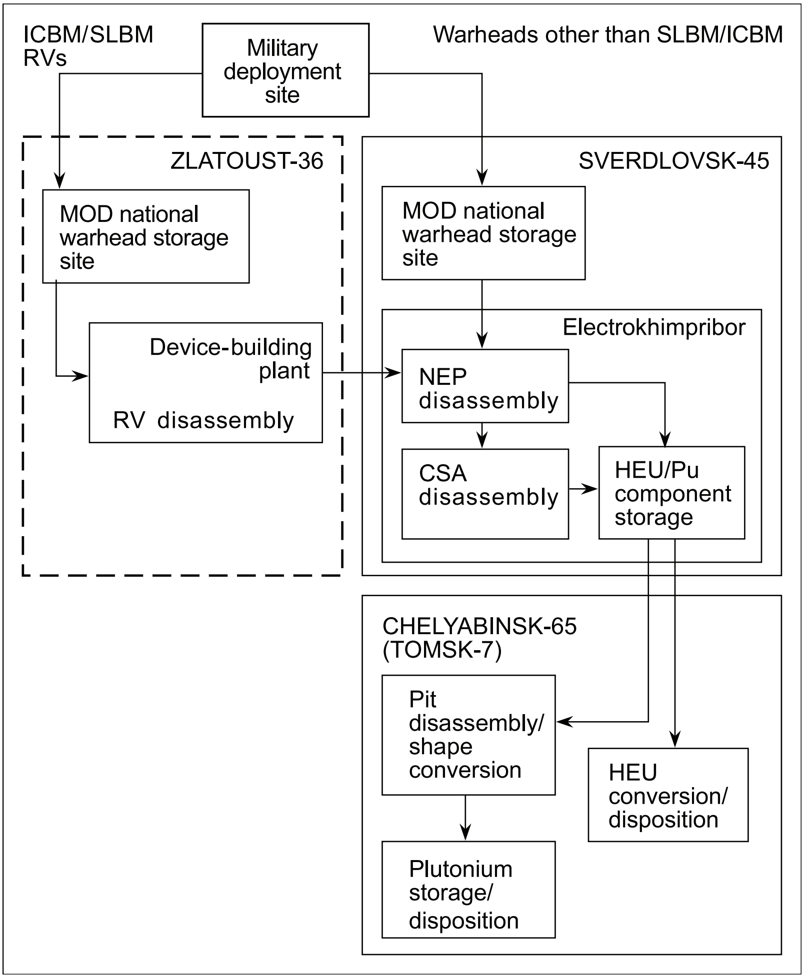

Figure 9.1. A hypothetical scenario of warhead dismantlement in Russia

CSA = canned sub-assembly; HEU = highly enriched uranium; ICBM = intercontinental ballistic missile; MOD = (Russian) Ministry of Defence; NEP = nuclear explosive package; Pu = plutonium; RV = re-entry vehicle; SLBM = submarine-launched ballistic missile.

After interim storage at the dismantlement plants, containers with HEU and plutonium components recovered from nuclear warheads are shipped to Chelyabinsk-65 or Tomsk-7. At these two facilities, HEU components are reduced to metal shavings and converted to purified uranium oxide powder, which is transferred to other facilities for fluorination and down-blending under the provisions of the 1993 US–Russian HEU Agreement.[10] Plutonium is

[10] US Department of Energy (DOE), *Megatons to Megawatts: Implementing HEU Transparency Measures* (DOE: Washington, DC, 1999); and Miller, J., 'Russia and US sign a nuclear deal', *International Herald Tribune*, 29 Mar. 1999, p. 5. The text of the HEU Agreement is reproduced in *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), pp. 673–75. See also Kile, S., 'Nuclear arms control and non-proliferation', *SIPRI Yearbook 2000* (Oxford University Press: Oxford, 2000), pp. 462–63.

expected to remain in storage pending its disposition as plutonium–uranium mixed oxide (MOX) fuel in power reactors. In 1998 the chemical and metallurgical plant at Chelyabinsk-65 began converting plutonium pits into 2-kg metal spheres for storage in the modern high-security Mayak facility, which is being built with US assistance.[11]

III. The US DOE nuclear weapon complex and warhead dismantlement operations

The US warhead production complex has been downsized considerably since the end of the cold war. It currently consists of eight facilities (table 9.2).[12] The complex is projected to retain its current structure for the foreseeable future, with consolidation of nuclear weapon activities and restructuring taking place within individual facilities.[13] Future deep reductions in nuclear weapons might lead to further contraction of the complex, including a transfer of certain production functions to national weapon laboratories and the closure of some facilities. For example, for a stockpile of a few hundred weapons, US warhead maintenance and refurbishment operations could eventually be moved to the Device Assembly Facility (DAF).

Two facilities in the US nuclear weapon complex are currently directly involved in warhead assembly–disassembly operations and are therefore likely to be part of a future monitoring regime. The dismantlement of intact warheads and the storage of plutonium pits both take place at the Pantex plant outside Amarillo, Texas. Pantex is the primary DOE facility capable of handling warhead assemblies that contain both HE and fissile materials. Another facility, the Y-12 plant in Oak Ridge, Tennessee, manages and disassembles HEU secondaries. Spare secondaries, HEU and lithium-6 deuteride thermonuclear fuel are also stored at the Y-12 plant.

Two other US facilities could be involved in a future transparency regime. The first facility, the DAF, is located at the Nevada Test Site.[14] It is a state-of-the-art safe and secure facility that was originally designed to assemble nuclear explosive devices for underground testing and is now primarily used for supporting the DOE's subcritical experiments and for training It has Pantex-type warhead assembly–disassembly bays and cells as well as staging areas for war-

[11] US Department of Defense (DOD), 'Cooperative Threat Reduction program', US DOD/DTRA/CTR briefing materials (slides), 3 Mar. 1998. For a discussion of the Mayak storage facility, see chapter 5 in this volume.

[12] For a general description and history of the US nuclear weapon complex see Cochran, T. *et al.*, *Nuclear Weapons Databook, Vol. III*: *US Nuclear Warhead Facility Profiles* (Ballinger: Cambridge, Mass., 1987); and US Department of Energy (DOE), *FY 2000: Stockpile Stewardship Plan*, Sanitized Version (DOE Office of Defense Programs: Washington, DC, 15 Mar. 1999).

[13] The DOE is developing a contingency plan for the future construction of a new plutonium pit manufacturing facility, possibly at the Savannah River site. See US Department of Energy (note 12).

[14] McElroy, L., 'Device Assembly Facility: new facilities for handling nuclear explosives', *Science and Technology Review*, May 1998, available at URL <http://www.llnl.gov/str/05.98.html>. The DAF has 5 assembly–disassembly cells and 7 bays.

Table 9.2. The US DOE nuclear warhead production complex, 2001

Facility	Location	Nuclear warhead production functions
Los Alamos National Laboratory (LANL)	Los Alamos, New Mexico	Basic R&D and advanced technologies development Nuclear weapon physics experiments Maintenance of capability to design/certify NEPs Stockpile safety/reliability assessments Pit surveillance, modification, fabrication Production and surveillance of non-nuclear components[a]
Lawrence Livermore National Laboratory (LLNL)	Livermore, California	Basic R&D and advanced technologies development Nuclear weapon physics experiments Maintenance of capability to design/certify NEPs Stockpile safety/reliability assessments
Sandia National Laboratories (SNL)	Albuquerque, New Mexico	Non-nuclear components and systems R&D and engineering Nuclear weapon tests and experiments on weapon effects Manufacturing of neutron generators and select non-nuclear components Stockpile safety/reliability assessments
Kansas City Plant	Kansas City, Missouri	Production of non-nuclear components (electrical, mechanical materials) Surveillance, testing, repair of non-nuclear components
Pantex Plant	Amarillo, Texas	Assembly, surveillance and maintenance of nuclear warheads Dismantlement of retired warheads Production of HE components Storage of plutonium pits
Oak Ridge Y-12 Plant	Oak Ridge, Tennessee	Surveillance of thermonuclear CSAs Maintenance of capability to produce CSAs and radiation cases Dismantlement of CSAs of retired warheads Storage of HEU and lithium materials and parts Production support to national laboratories
Savannah River Site	Aiken, South Carolina	Recycling/loading of tritium Surveillance of tritium reservoirs Support of tritium source projects Pit conversion and disposition (planned) Pit manufacturing (possible in the future)
Nevada Test Site	Las Vegas, Nevada	Maintenance of capability to conduct/ evaluate underground nuclear tests Nuclear weapon physics experiments Emergency response and radiation sensing support

Facility	Location	Nuclear warhead production functions
DOE warhead complex facilities shut down after 1985		
Rocky Flats Plant	Denver, Colorado	Pit manufacturing Production of beryllium and other non-nuclear components
Mound Laboratory	Miamisburg, Ohio	Fabrication/surveillance of non-nuclear warhead components
Pinellas Plant	St Petersburg, Florida	Production of neutron generators and other non-nuclear warhead components
Hanford Reservation	Hanford, Washington	Plutonium production

CSA = canned sub-assembly; HE = high-explosive; HEU = highly enriched uranium; NEP = nuclear explosive package; R&D = research and development.

[a] In addition to pits production LANL is assigned responsibilities for detonator production and surveillance, neutron tube target loading, beryllium component manufacturing, non-nuclear pit parts production, mock pits production, surveillance of radioisotopic thermoelectric generators (RTGs) and certain valves.

Sources: Cochran, T. *et al.*, *US Nuclear Warhead Facility Profiles*, *Nuclear Weapons Databook, vol. III* (Ballinger: Cambridge, Mass., 1987); and US Department of Energy, *FY 2000: Stockpile Stewardship Plan*, Sanitized Version (DOE Office of Defense Programs: Washington, DC, 15 Mar. 1999). This table also appears in Bukharin, O., 'The changing Russian and US nuclear warhead production complexes', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 594–95.

head and nuclear component storage.[15] The DOE is considering the DAF as a possible dedicated facility for the dismantlement of treaty-limited warheads.

A Pit Disassembly and Conversion Facility (PDCF) which the DOE plans to construct at the Savannah River site in South Carolina is another facility in line for dismantlement operations. The PDCF is projected to begin operations in 2005 and would disassemble pits, convert plutonium metal to oxide, remove gallium (an alloying material for plutonium in warheads), and package and ship plutonium oxide to other plutonium disposition facilities. It would also recover and decontaminate HEU components of composite pits before they are shipped to the Y-12 plant.[16]

Warhead dismantlement

In the USA, the warhead retirement and elimination process is carried out according to a nuclear weapon stockpile plan, developed jointly by the Depart-

[15] Disassembly cells are used to conduct operations with uncased explosives and fissile material components. If conventional explosives detonate, disassembly cells are designed to vent such explosions and trap fissile materials. Operations with uncased insensitive high explosives and fissile materials may be performed inside a disassembly bay. Pantex has 13 disassembly cells and 60 bays.

[16] Los Alamos National Laboratory, 'Status of the pit disassembly and conversion facility (PDCF)', LANL briefing materials (slides), 12 Nov. 1998.

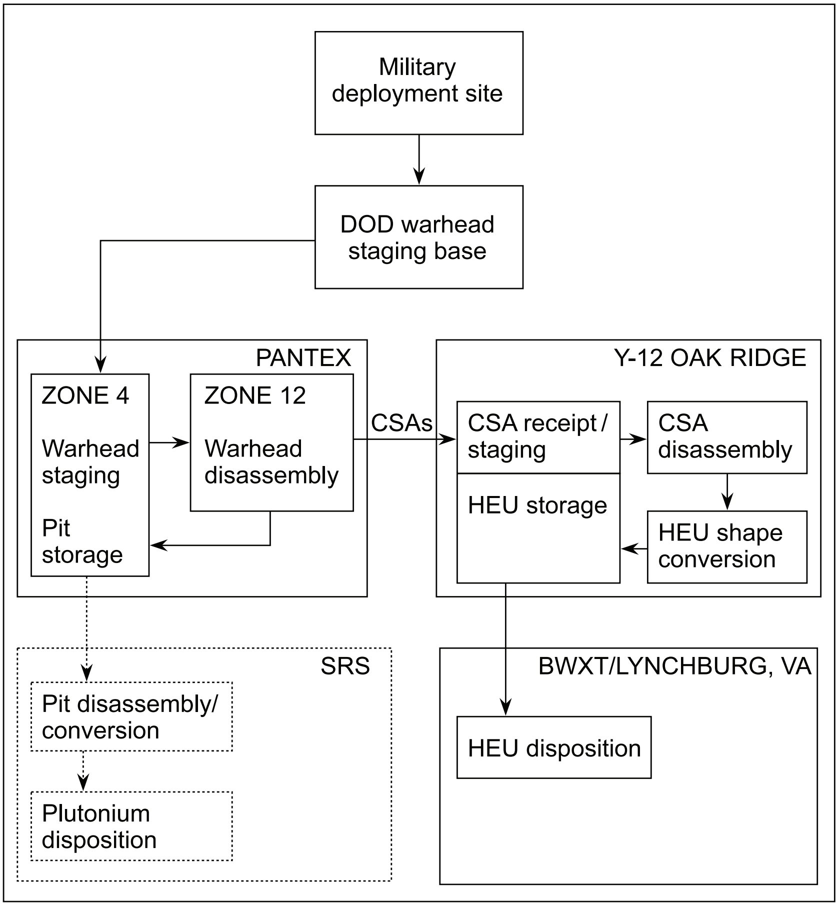

Figure 9.2. Warhead dismantlement in the USA

BWXT = BWX Technologies; CSA = canned sub-assembly; DOD = Department of Defense; HEU = highly enriched uranium; SRS = Savannah River Site.

ment of Defense (DOD), the DOE and the Joint Chiefs of Staff and approved by the president.[17] After an administrative retirement decision is made, retired warheads are separated from their delivery systems and, if they are not already in storage, moved to a storage depot of the respective military service.[18] From a military depot, retired warheads are picked up by a safe and secure trailer (SST) operated by the DOE Transportation Safeguards Division (TSD). Then the TSD personnel assume custody of the warheads. Depending on the dismantlement

[17] A nuclear weapon stockpile plan, which is referred to as a nuclear weapon stockpile memorandum prior to presidential approval, is a classified document which annually updates stockpile projections for the next 5 years and specifies the number and types of nuclear warheads to remain in the stockpile or be retired. US Congress, Office of Technology Assessment (OTA), *Dismantling the Bomb and Managing the Nuclear Materials*, OTA-O-572 (US Government Printing Office: Washington, DC, Sep. 1993), p. 20.

[18] The Air Force and the Navy are the only military services with nuclear weapons. All nuclear weapons were withdrawn from the US Army and Marine Corps in the past decade.

schedules and availability of storage capacity at DOE facilities, warheads can also be pre-staged at the Kirtland Air Force Base in Albuquerque, New Mexico, before they are shipped to DOE facilities.[19]

Retired warheads are shipped to Pantex (figure 9.2). The Pantex plant consists of several technical areas that are commonly referred to as 'zones'.[20] Warhead dismantlement operations are supported by two such areas—Zone 4 and Zone 12. The TSD SSTs typically bring warheads to Zone 4, where they are temporarily placed inside storage magazines (earth-covered bunkers). Within 72 hours of delivery, warheads undergo safeguards and safety checks to confirm their identity and determine their technical status.[21]

A batch of retired warheads is then moved to Zone 12, Pantex's primary production area. After initial documentation and safety checks, a retired warhead is moved to a disassembly bay, where it is removed from the shipping container and where most mechanical disassembly operations are performed.[22] These include the separation of the NEP, the tritium reservoir (if it has not already been removed), and principal mechanical and electronic sub-assemblies. The NEP is then moved to a dismantlement cell (also known as a 'Gravel Gertie'), where it is further disassembled to separate the thermonuclear secondary—also known as the canned sub-assembly (CSA)—the HE components and the pit. The dismantlement process takes from five days to three weeks to complete, depending on the warhead type and facility workload.[23]

Sealed plutonium pits are placed inside steel storage containers and are moved to Zone 4 magazines for storage.[24] Secondary sub-assemblies, which contain HEU and lithium-6 deuteride components, are placed in shipping containers and staged in Zone 12 prior to shipment to the Y-12 plant for further disassembly or storage. Tritium reservoirs are sent to the Savannah River facility for tritium storage and recycling. HE components are burned on Pantex grounds. Other non-nuclear components, if not intended for reuse, are sorted, sanitized to remove classified information, and sent to other DOE facilities or commercial companies for recycling, recovery of valuable materials or disposal. Classified waste is disposed of at the Nevada Test Site.

HEU secondaries are delivered by TSD SSTs to the Y-12 plant. There, the secondaries are disassembled, and HEU components are staged for storage or are melted and recast into cylinders that are then placed in storage prior to dis-

[19] Arkin, W., Norris, R. S. and Handler, J., *Nuclear Weapons Databook: Taking Stock: Worldwide Nuclear Deployments 1998* (National Resources Defense Council: Washington, DC, Mar. 1998), p. 63, available at URL <http://www.nrdc.org/publications/default.asp#nuclear>.

[20] See, e.g., US Department of Energy, Office of Oversight, 'Pantex plant: site profile', Washington, DC, June 1998, URL <http://www.globalsecurity.org/wmd/facility/pantex.htm>.

[21] These inspections could be conducted in either Zone 4 or Zone 12.

[22] For a general description of warhead dismantlement processes see US Department of Energy (DOE), *1998 Programmatic Information Documents for Pantex Plant* (DOE: Washington, DC, 1998). A discussion of warhead dismantlement at Pantex can be found in Cameron, K., 'Taking apart the bomb', *Popular Science*, Apr. 1993, pp. 64–69, 102–103.

[23] US Department of Energy (DOE), *Dismantlement of Nuclear Weapons and Stage Right* (documentary video film, n.d.), DOE, Pantex, Amarillo, Tex.

[24] For a general description of disposition of nuclear weapon materials see US Congress, Office of Technology Assessment (note 17), p. 34.

posal. The disposition of HEU from the Y-12 plant began in 1999 at the BWX Technologies (BWXT) plant in Lynchburg, Virginia.[25] The contract envisages the down-blending of 50 tonnes of HEU by 2005. In the future, HEU down-blending could also be performed at other private and/or DOE facilities.

IV. The impact of transparency measures on facility operations

The presence of foreign inspectors and the implementation of other transparency measures would have a profound impact on warhead dismantlement facilities. Neither the Russian nor the US facilities were designed to accommodate inspections. Both the warhead dismantlement and stockpile stewardship operations are presumably conducted in the same buildings, even the same rooms, and carried out by the same personnel and with the same equipment. The problem might be particularly serious for Russia, which is believed to maintain a higher warhead re-manufacturing rate because of the short lifetimes of its warheads.[26]

Transparency measures would affect both dismantlement and active stockpile operations. Efforts to prepare a facility for a monitoring regime would require considerable resources, such as construction personnel and equipment, and could interfere with or even force a temporary closure of some of the production operations. Transparency activities might compete for resources (such as security personnel, infrastructure, and maintenance and support services) with ongoing facility operations. Personnel and materials traffic would have to be re-routed around the areas occupied by inspectors.

Furthermore, transparency measures could slow down and complicate the dismantlement process. For example, the use of radiation-detection techniques would require equipment calibration and maintenance, personnel training and time to conduct measurements. Radiation-detection equipment would have to be installed in a separate room in the facility. The additional movement of nuclear warheads and materials, the use of active radiation-detection techniques and the presence of high explosives would also raise various health and safety issues.

Meeting the requirements for the protection of information is another challenge. Much of the information to which inspectors would have access through their observations (e.g., a facility's safeguards and security systems and procedures, and warhead transportation arrangements) is classified and must not be revealed without a government-to-government agreement that authorizes such an exchange. Clandestine environmental sampling by inspectors is a concern

[25] Wallack, W., 'BWXT expects to complete downblending of 50 metric tons of HEU by mid-2005', *Nuclear Fuel*, 27 Nov. 2000, pp. 5–6. BWXT also receives HEU from the uranium enrichment facility in Portsmouth, Ohio.

[26] Assuming an average warhead lifetime of 10–15 years for current-generation Russian warheads and a START III stockpile of 5000 deployed and reserve strategic and tactical warheads, the remanufacturing requirements would be 300–500 warheads per year. In contrast, the lifetime of US warheads is *c.* 30 years. For a stockpile of the same size, *c.* 150–200 warheads might therefore be remanufactured each year in the USA. This asymmetry will be eliminated when (and if) Russia adopts longer-life nuclear warheads.

since it could reveal information about materials used in nuclear warheads. Information that indicates the levels of or variations in production could also be sensitive. For example, a sharp increase in operations, when collated with information from satellite surveillance or other sources on warhead shipments from military units, could indicate that there had been a massive recall of a certain type of warhead because of a fault or failure.

Proper timing of stewardship activities, rigorous escorting procedures and masking of sensitive equipment could reduce the negative impact on operations and security. Segregation of transparent warhead dismantlement activities within isolated areas could be another helpful tool. A dedicated dismantlement monitoring area would contain a preparations area for warhead authentication procedures, disassembly bays and cells with a capacity to accommodate a projected rate of dismantlement of treaty-limited warheads and support facilities (e.g., staff rooms) for inspectors.

A hypothetical protocol for warhead dismantlement transparency monitoring is shown in figure 9.3. The area would be surrounded by a solid, opaque wall preventing inspectors from observing the rest of the plant's grounds and would be connected to a facility entrance by a walled-off road. The construction of a new, dedicated warhead dismantlement area at a distance from the main protected area of the existing facility would be another option.

Segregation could even include isolation of the dismantlement of treaty-limited warheads in dedicated facilities. However, this would probably require considerable retooling of facility production lines and personnel training.[27] It is unlikely that a government would decide to use an operating facility for transparent warhead dismantlement unless the state was a party to a formal arms control agreement and unless dismantlement activities were extensive enough to justify such a decision on economic grounds.

In Russia, the projected closure of the Avangard plant provides an opportunity to convert it into a dedicated dismantlement facility. However, a monitoring regime will not be in place before 2003, when the plant is scheduled to stop warhead dismantlement work. Restarting it after closure could be an expensive and lengthy process.[28]

In the USA, treaty-limited warhead dismantlement operations could be carried out at the DAF facility. (Pantex and Y-12 would continue to store fissile material components.) It is obvious that numerous operational and security benefits would be gained by using the DAF but also that significant additional investments would be required to prepare it for this activity.

[27] In Russia, retired warheads are dismantled at the same facility where they were originally assembled. See, e.g., Andryushin, I. *et al.* (eds), [Safety of Russia's nuclear weapons] (Russian Ministry of Atomic Energy, Bell-Atom, LCC: New York, 1998), p. 11 (in Russian). The use of a dedicated dismantlement facility would be likely to violate this safety and production rule. Whether such a violation would be acceptable is not known.

[28] Further downsizing of the Russian nuclear complex could make another facility (e.g., in Zlatoust-36) available for conversion to a dedicated warhead transparency centre.

A PROTOCOL FOR TRANSPARENCY IN WARHEAD DISMANTLEMENT

A transparency monitoring protocol, defining specific monitoring procedures and actions by inspector and host parties in relation to the flow of nuclear warheads and materials through the warhead retirement and dismantlement process, is a central element of any future monitoring regime. According to one proposed protocol, transparency and monitoring measures would start at a military deployment site. Inspections at military sites might start at a lower warhead stockpile level. The description of the steps in the process can also be traced in the diagram in figure 9.3.

After a warhead had been removed from a missile, a joint Russian–US inspection team would conduct the following measurements: (*a*) measurements of the warhead's unclassified external parameters (e.g., for a missile warhead, these could include total length, total weight, radius at nose blunting, diameter at a rear, nose-cone angle and centre of mass position); (*b*) attribute measurements for fissile material; and (*c*) attribute measurements for HE components.

The warhead would then be loaded into a transportation container, which would be tagged and double-sealed by Russian and US inspectors. The seals would then be continuously watched by a video camera (a technique known as dynamic seal monitoring) until the warhead was delivered for disassembly to a dismantlement facility.

Upon its arrival at a dismantlement facility the warhead would be moved to a dedicated preparations facility where Russian and US inspectors would re-measure its external parameters as well as its HE and fissile material attributes. The 'authenticated' warhead would then be moved to a disassembly area.

Prior to dismantlement, inspectors would sweep the disassembly area with radiation detectors to ensure that it did not contain undeclared warheads or fissile material. The facility operators could cover any equipment that might reveal information about warhead design. The inspectors would not stay to observe the disassembly process. However, they would be permitted to carry out radiation measurements on all containers entering and leaving the disassembly area to confirm that no fissile material had been secretly introduced to or removed from this area. After the disassembly process had been completed, they would again sweep the area to verify that all the fissile material had been removed. This would associate the materials in the fissile material containers leaving the disassembly area with the original warhead. This process would be repeated more than once as the warhead and its components went through successive stages of dismantlement.

The containers holding the stripped-down fissile components would be tagged, sealed and sent to a monitored storage facility pending final disposal of the fissile material. To increase confidence, the inspectors could audit the facility's records and track non-nuclear components, such as warhead casings and HE components, until they were destroyed.

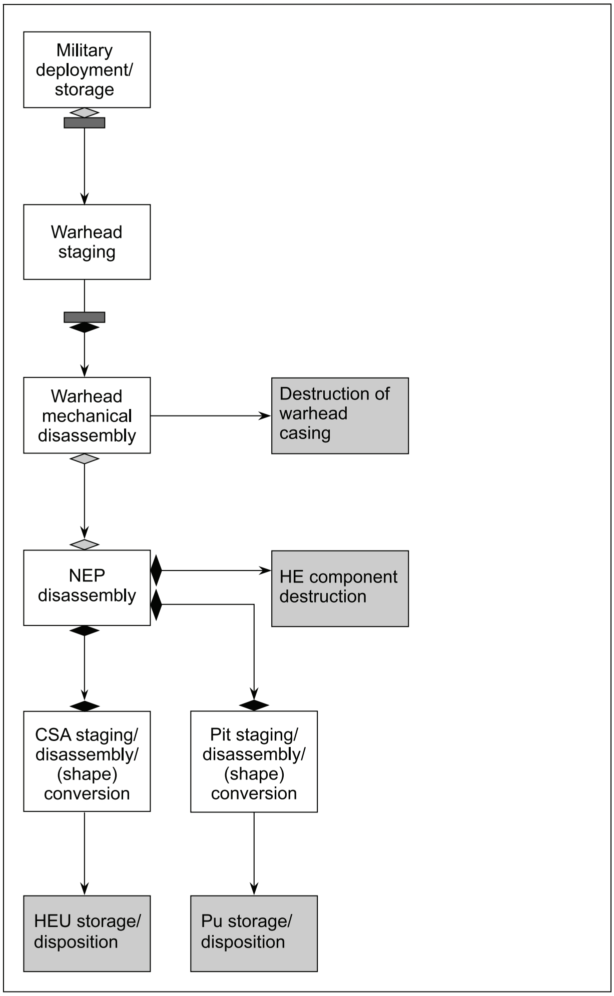

Figure 9.3. A hypothetical protocol for warhead dismantlement transparency: sequence and monitoring

CSA = canned sub-assembly; HE = high-explosive; HEU = highly enriched uranium; NEP = nuclear explosive package; Pu = plutonium.

Key: Diamond-shaped symbols = measurement of radiation; black diamonds = measurements of Pu/HEU using an attribute measurement system with an information barrier (AMS/IB) and portable isotope neutron spectroscopy for HE; grey diamonds = possible measurements; grey shaded boxes = managed access; dark grey rectangles = possible measurement of warhead external parameters; arrows = chain of custody.

A combination of methods is best. For warheads: NEPs, HEU/Pu sub-assemblies and components, documentation review, external parameters, AMS/IB, limited chain of custody and portal monitoring. For fissile materials: documentation review, containment and surveillance, weighing, radiation measurements, inspection and inventory.

Source: The protocol is based mainly on Dubinin, V. and Doyle, J., *Item Certification for Arms Reduction Agreements: Technological and Procedural Approaches* LA-UR-00-2740 (Los Alamos National Laboratory: Los Alamos, N. Mex., 2000).

It is also possible that the most cost-effective and balanced approach would involve the construction of new warhead dismantlement facilities that are specifically designed to operate for a limited period (e.g., for the duration of a treaty) and to accommodate inspections.

V. Asymmetries of warhead complexes

During the cold war, Russia and the USA each developed a dedicated infrastructure to design, test, mass-produce and support the field deployment of tens of thousands of nuclear warheads. The Russian and US complexes exhibit important differences in structure and organization as well as in stockpile management and warhead dismantlement practices. These asymmetries, some of which are not yet fully understood, at least at the unclassified level, as well as differences in national classification and security requirements, could necessitate somewhat different inspection and monitoring procedures at the facilities in each state. Negotiating and implementing such asymmetric monitoring would be difficult and would require flexibility and goodwill on both sides.

Number and functions of the Russian and US dismantlement facilities

Most of the monitoring options that have been proposed by Russian and US laboratory experts call for limited chain-of-custody procedures and radiation measurements for nuclear weapons and fissile materials (see figure 9.3), which, at a minimum, would require access to both warhead dismantlement plants and fissile material storage and disposition facilities.[29]

Six Russian facilities are involved in warhead dismantlement operations, compared to two facilities in the USA. Without major modifications and retooling of the Russian weapon complex, it would be difficult to designate any single Russian facility for the verified dismantlement of warheads. The monitoring of operations might therefore require access to a larger number of facilities in Russia than in the USA.

Consolidation of the Russian weapon complex is likely to alleviate this problem. By about 2003 the number of facilities that directly support warhead dismantlement operations will have declined from six to four—the warhead dismantlement facilities in Sverdlovsk-45 and Zlatoust-36 and the plutonium/HEU storage and disposition facilities in Chelyabinsk-65 and Tomsk-7. The process of infrastructure reductions in Russia and the construction of the PDCF facility in the USA would then largely eliminate the asymmetry in the numbers of monitored facilities.

Additional complications could arise because Russian and US facilities are probably not fully equivalent functionally. For example, if disassembly operations for certain Russian warheads are carried out sequentially in Zlatoust-36 and Sverdlovsk-45, it could be necessary to implement additional chain-of-

[29] Russian and US technical experts and security officials have not agreed on a transparency protocol.

custody procedures for NEPs or other major sub-assemblies. These procedures would be followed, starting from mechanical disassembly of nuclear warheads in Zlatoust-36 and continuing until their final dismantlement in Sverdlovsk-45.

The Sverdlovsk-45 plant may disassemble not only intact warheads and NEPs but also thermonuclear secondaries. In that case, more than one technical area would have to be subjected to inspections in Sverdlovsk-45. (US inspectors would also monitor HEU storage and disposition in Chelyabinsk-65 and Tomsk-7.)

Financial capabilities

The DOE has estimated that hosting an initial inspection at Pantex would cost $6 million and that hosting subsequent inspections would cost $2.5 million per year.[30] The initial costs would include those for building fences and portals around a segregated disassembly area, masking sensitive activities and training security personnel. Preparation costs at the Y-12 plant could be even higher if, as proposed by some DOE experts, a decision is made to construct a new dismantlement and fissile material storage facility.

The costs could be still higher in Russia because its facilities are larger and more complex. Russian experts have concluded that special buildings for preparations for warhead authentication procedures and new dedicated dismantlement areas would need to be constructed.[31]

The USA has effectively been funding warhead transparency technology development in Russia through laboratory-to-laboratory contracts.[32] It has also indirectly supported Russia's dismantlement work by purchasing uranium derived from HEU from dismantled warheads under the HEU Agreement. Facility preparations and inspections would require additional, presumably internal, funding. This might be a serious disincentive for Russia to implement warhead transparency measures.

Technical approaches

There are also significant differences in the nuclear weapon technologies to which states have access and national technical policies. For example, while the

[30] The annual cost estimates assume 12 routine inspections per year. It was assumed that inspections would take 5 days and an inspection team would consist of 10 inspectors. (The estimates do not take into account the cost of inspection equipment.) In addition, the US Defense Threat Reduction Agency, which has absorbed the On-Site Inspection Agency, would spend an estimated $200 000 per year to provide escorts and logistical support to inspectors. See, e.g., Bukharin, O. and Luongo, K., *US–Russian Warhead Dismantlement Transparency: The Status, Problems, and Proposals*, PU/CEES Report no. 314 (Princeton University, Center for Energy and Environmental Studies (PU/CEES): Princeton, N.J., Apr. 1999).

[31] Voznyuk, R. (VNIITF), Remarks at the Institute of Nuclear Materials Management's Annual Meeting, New Orleans, La., 16–20 July 2000.

[32] In 2000 the US technology development effort (much of it domestic) was funded at a level of $25.1 million. Concher, T. R. and Bieniawski, A. J., 'Transparency questions looking for technology answers', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

USA stores plutonium from retired weapons in the form of pits, Russia has already started to convert pits into metal spheres prior to long-term storage at the US-funded facility under construction at the Mayak complex in Chelyabinsk-65. According to a US congressional requirement, the DOD must verify that plutonium to be placed in this facility is taken from retired weapons. Because pit conversion makes such verification impossible, the DOD is under pressure to negotiate with the Russian Government a set of appropriate transparency measures for the pit conversion point. The proposed agreement is referred to as the Processing and Packaging Implementation Agreement (PPIA).[33]

Role of the military

Another difference between the Russian and US procedures is the greater role of the military in the Russian warhead management and dismantlement process. In the USA, the DOD's involvement in warhead management operations ends after the DOE's safe and secure trailer picks up a weapon at a military base to deliver it to Pantex for dismantlement. In Russia, prior to dismantlement, warheads are kept at MOD-controlled storage facilities, some of which are collocated with the dismantlement plants. Reportedly, military representatives also observe the process of dismantlement. US inspectors would therefore be involved with both Minatom and the MOD.

Production capacities

In addition to the asymmetries in the number and structure of facilities where warhead dismantlement takes place, there are also differences between Russia and the USA in nuclear warhead production.

The US industrial infrastructure for mass production of nuclear warheads has shrunk considerably since the late 1980s. Many warhead production and management activities have been consolidated and/or transferred to the DOE's national laboratories, and a number of manufacturing facilities have been closed down.

In Russia, the re-manufacturing of new warheads has also declined and, as of 1999, it was at one-twelfth of its 1990 level (presumably in the low hundreds of warheads per year).[34] However, the Russian weapon complex is still oversized and might have the capacity to produce thousands of new warheads each year.

Russia's large production capacity has raised significant concerns, particularly among some Republican members of the US Congress.[35] US critics of the

[33] Under the US proposal, verification procedures would involve attribute measurements on plutonium components using the attribute measurement system with an information barrier (AMS/IB system). See appendix 8A in this volume. For a descripition of the PPIA see chapter 5 in this volume.

[34] ['We must save the best'] (Press Conference with L. Ryabev), *Gorodskoy Kuryer* (Sarov), 5 Mar. 1998 (in Russian).

[35] E.g., Senator Jesse Helms, former chairman of the Senate Foreign Relations Committee, has objected to warhead transparency arrangements because 'Russia could be expected simply to replace dismantled

proposed warhead transparency measures could be expected to use the asymmetry in production capacity to support two of their concerns: first, that Russia could use its excess production capacity to secretly produce new warheads to replace warheads that have been dismantled under arms control commitments; and second, that Russia could quickly reconstitute its warhead arsenal in a breakout scenario during a period of increased international tension.

A closer examination of the problem of warhead production capacities suggests, however, that it may not seriously destabilize the strategic balance.

First, the USA is planning to retain large stockpiles of fissile material components, and hedge and reserve warheads, which number in the thousands. Also, Russian secret or breakout production of new strategic warheads would make little sense if Russia had already eliminated the associated delivery vehicles.[36]

Second, although the US weapon production capability has been reduced, it is still significant. For example, the Pantex plant has a capacity to produce approximately 1100 warheads per year, compared to the cold war production level of 2000 warheads per year.[37] Other key DOE facilities also maintain a sizeable production capacity.[38]

The USA currently lacks an industrial-scale capability to produce plutonium pits. The Rocky Flats plant outside of Denver, Colorado, which produced pits in the past, was closed down in 1989 because of environmental and safety concerns. However, the Los Alamos National Laboratory (LANL), the only US facility with complete plutonium-handling capabilities, is expected to reach a manufacturing capacity of 20 plutonium pits per year by 2007. Eventually, it would be able to produce 50 (with a surge capacity of 80) pits per year. This capability is generally viewed as sufficient to maintain the US stockpile. The DOE is also developing a contingency plan that would allow the USA to have a manufacturing facility capable of producing 500 pits per year within five years of a decision to build one.[39] In the interim, any new large-scale production of nuclear weapons could rely on already stored pits.

Third, the Russian warhead production capacity is considerably smaller than it was in the past and will decrease further.[40] Russia has closed down (or plans to close down) major facilities in each of the sectors of the warhead production cycle, including manufacturing of mechanical and electronic components, pro-

older warheads with newer models, while the United States foots the bill for destruction'. Senator Helms' letter to Secretary of Energy Federico Pena, 16 Sep. 1997, in Bukharin and Luongo (note 30).

[36] Some strategic air-launched warheads could probably be deployed with medium-range bombers for sub-strategic missions.

[37] Pantex's capacity is dependent on the complexity and mix of specific weapon systems and activities (dismantlement, disassembly and inspection, rebuilding, etc.). E.g., the disassembly and inspection capacity alone is 250–350 warheads per year. US Department of Energy (note 12).

[38] The Oak Ridge Y-12 plant maintains the capability to manufacture 300 secondaries per year, compared to 1500 secondaries per year during the cold war. The Savannah River tritium facility is capable of recycling/reloading 2500 reservoirs per year, compared to 6000 reservoirs per year in the past. US Department of Energy (note 12).

[39] US Department of Energy (note 12), chapter 12, p. 8.

[40] The USSR's warhead production capacity peaked in the mid- to late 1980s. Assuming an operational Soviet stockpile of 35 000 warheads and a warhead lifetime of 10 years, it can be assumed that the Soviet complex was manufacturing and refurbishing 3500 warheads per year in the mid-1980s.

duction of fissile material components and final assembly of nuclear warheads. Nuclear weapon activities are being consolidated in a smaller number of buildings at the remaining facilities of the complex. Minatom's nuclear weapon workforce is being reduced from about 130 000 to 35 000 workers.[41]

Fourth, because of the significant differences in the technical approaches to stockpile surveillance and management practices, it is impossible to compare the Russian and US weapon complexes. In particular, Russia has to maintain a relatively high production capacity, in part because of manufacturing and technology problems that limit the lifetime of the current-generation warheads to 10–15 years.[42] By comparison, US warheads have a service life of 25–30 years. Russia therefore has to re-manufacture two to three times as many warheads to maintain a nuclear arsenal of the same size. Generally speaking, the Russian weapon complex is likely to require more infrastructure to support a stockpile of comparable size.

To a significant extent, US concerns about Russia's production capacities are based on a lack of credible information about the Russian nuclear weapon programme. In contrast, the US programme is vastly more transparent. For example, detailed official data on the production and inventories of plutonium are in the public domain, and similar data on HEU are being prepared for release. A great deal of information is also available about the missions, production capacities and organization of US nuclear weapon facilities. Greater openness in Russia is a prerequisite for a future transparency scheme.

Concerns about production asymmetries could be alleviated through cooperative transparency measures. Initially, such transparency measures could include warhead stockpile and manufacturing declarations, as well as monitoring of the production facilities that no longer manufacture new warheads. Eventually, transparency arrangements could also be implemented at the remaining active warhead production facilities.

VI. Moving forward

Major issues

Building warhead transparency would involve addressing the following interrelated political, technical and operational issues.

[41] Preobrazhenskaya, E. and Gorlova, E., ['On problems of Russia's atomic industry under conditions of restructuring'], *Bulletin of the Center of Public Information (*Moscow, Central AtomInform Institute), no. 7 (1993), pp. 5–11 (in Russian).

[42] Reportedly, some problems of ageing of Russian warheads relate to corrosion and the swelling of (presumably, fissile material) components. See, e.g. [Stenographic Records of the Parliamentary Hearings 'Safety and Security Problems at Radiation-Hazardous Facilities 25 Nov. 1996'], *Yaderny Control*, no. 34–35 (Oct./Nov. 1997), pp. 7–11 (in Russian). However, Russia has reportedly launched a programme to improve its warhead manufacturing techniques in order to extend warhead lifetimes. Remarks by A. Diakov at the Workshop on the Future of Russian–US Arms Reductions: START III and Beyond, Massachusetts Institute of Technology, Boston, Mass., 2–6 Feb. 1998.

Policy

To be successful, transparency measures would need to be designed in such a way as to help each country meet its clearly defined political and arms control objectives. Implementation would also probably require a legally binding agreement between governments. Little progress has been made on the policy front. In Russia, several key agencies and organizations remain sceptical about warhead transparency. Some policy makers believe that it would be of little benefit to Russia, that the associated costs would be high, and that the main US objective in pursuing warhead transparency is to collect intelligence on the Russian nuclear complex and operations. Negative views on warhead transparency exist in the USA as well. This problem has been further complicated by the more stringent security and counter-intelligence policies of both states.

Technology

Warhead transparency would not be possible without mature monitoring technologies that provide for a sufficient degree of confidence in the verification of the elimination of nuclear warheads and that allow each country to protect sensitive and classified information. As a result of US domestic efforts and the bilateral Russian–US laboratory-to-laboratory warhead dismantlement transparency programme, considerable progress has been made in the area of technology development (see appendix 8A). An attribute measurement system with an information barrier (AMS/IB) for measurements on plutonium components is ready for deployment. Major advances have been made in the area of chain-of-custody technologies, including seals, tags and seal monitoring. There are also promising ideas and projects in other areas, including non-nuclear warhead monitoring technologies and the control and monitored disposition of HE components and warhead casings.

However, much remains to be done. There is no viable system to conduct passive radiation-detection measurements on HEU components. There is also a need to develop and validate an IB system for high-explosive component-detection measurements.

Operations

Transparency technologies and procedures need to be adaptable for implementation at the existing Russian and US nuclear weapon production complexes. They should be designed in a way that minimizes their impact on facility operations and their financial burden and that mitigates the political and perceptional problems associated with the considerable asymmetries between the two complexes. Indeed, in each country, transparency and inspection protocols must be vetted by all the participating agencies and organizations, including the military, weapon laboratories, and DOE and Minatom headquarters, production facilities, and security and classification agencies. Facility- and weapon system-specific preparations, including technology evaluations by operations and security experts, equipment certification, facility modifications, and development of inspection options and procedures, must also be completed.

This process is at a relatively advanced stage in the USA. In 1999, a Joint DOD–DOE Integrated Technology Steering Committee was established to work on monitoring technologies, impact–cost facility studies and demonstrations, and security and vulnerability analysis.[43] In the same year, a successful US-only demonstration of warhead-monitoring technologies took place at the Pantex plant. In 2000, US experts conducted for Russian counterparts a demonstration of an AMS/IB system on a classified plutonium component at LANL.

Security and classification experts are active participants in this effort.[44] In particular, they determine what information can be exchanged (or must be protected), develop functional requirements and application procedures for information barriers and other technologies, participate in 'red team' evaluations,[45] and support laboratory-to-laboratory workshops and demonstrations in the USA.

While information about Russia's internal efforts (outside of the laboratory-to-laboratory contracts) is not available, it is likely that progress is lagging. In the late 1990s, Russia's nuclear weapon institutes reportedly had a mandate to explore the feasibility of developing warhead transparency measures (but not to develop them).[46] While Russian laboratory experts are supportive of the laboratory-to-laboratory warhead transparency efforts, some other key Russian agencies appear to be less supportive.

A better understanding of the Russian and US dismantlement processes is one of the principal objectives of the laboratory-to-laboratory programme.[47] The programme supports a number of projects that seek to outline a hypothetical dismantlement process, evaluate the impact of a transparency regime on operations and develop monitoring protocols for a generic dismantlement facility. For example, the Computer Modeling System for Arms Control and Nonproliferation, under development at VNIITF in Russia and at the Sandia National Laboratories (SNL) in the USA, is designed to model warhead dismantlement processes and facilities and the corresponding monitoring scenarios and technology options.[48] However, the laboratory-to-laboratory programme is specifically limited to unclassified discussions: according to Russian experts, 'it would

[43] Concher and Bieniawski (note 32).

[44] Comerford, R. 'The role of security and classification in arms control and nonproliferation', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 32).

[45] Red team evaluations actively seek to defeat security and extract classified information.

[46] Remarks by a Russian nuclear weapon expert at the Russian American Nuclear Security Advisory Council (RANSAC) Workshop on New Perspectives for US–Russian Nuclear Security Cooperation, Moscow, 6–10 Apr. 1998.

[47] Bieniawski, A. and Irwin, P., 'Overview of the US–Russian laboratory-to-laboratory warhead dismantlement transparency program: a US perspective', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 32).

[48] Voznyuk, R. *et al.*, 'The Computer Modeling System for Arms Control and Nonproliferation', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 32).

be naïve to think that information on actual nuclear weapon operational procedures would be exchanged' in such projects.[49]

The first steps

While it will take considerable time and effort to resolve fundamental policy issues and to improve Russian–US relations, the two states could take a number of specific steps to facilitate the development of a workable transparency regime.[50]

Russian facility studies

To facilitate preparatory activities in Russia, the USA may have to fund Russian analyses whose results cannot be entirely shared with the USA. For example, a study of implementation arrangements for specific Russian facilities, development of information protection techniques and 'red team' evaluation would be of interest. In such cases, Russian experts could provide the USA with unclassified summaries of their classified reports.

Cooperative research on chain-of-custody arrangements for warheads

Another opportunity for the technical experts would be to extend their analysis 'upstream' to the US DOD and Russian MOD nuclear warhead deployment and storage sites. A starting point for this cooperation would be research on a possible transparent chain-of-custody arrangement for warheads as they move from active field deployment to dismantlement. This work would complement the laboratory-to-laboratory process and allow the Russian MOD to be more involved in the cooperation.

Familiarization visits to dismantlement facilities

Reciprocal visits to dismantlement facilities in order to familiarize both sides with the dismantlement processes are likely to be key to designing practical warhead transparency measures. The USA has proposed such a visit exchange.[51] According to DOE plans, Pantex was to be ready to host a foreign visit before fiscal year 2002. However, this proposal was not accepted by the Russian Government. A first step in this direction would be for each country to draw up, on paper, an unclassified description of activities at its dismantlement plants and a schematic diagram of how warheads flow through the dismantlement processes.

[49] Voznyuk, R. (VNIITF), Remarks at the Institute of Nuclear Materials Management's Annual Meeting, New Orleans, La., 16–20 July 2000.

[50] Some of the proposed steps are adapted from Bukharin and Luongo (note 30).

[51] A US 'non-paper' on reciprocal visits to dismantlement facilities was provided to Russian officials in 1994. Such visits would be designed to improve the understanding of site layouts and operational flow charts. They would involve a briefing on the facility's activities and a walk through its storage areas and dismantlement bays and cells.

Technology development centres

Russia and the USA should consider establishing technology development and demonstration centres at actual dismantlement facilities that are, or will be, non-operational. The planned phase-out of weapons work at the Avangard plant may present the best opportunity for a demonstration in Russia. Avangard is in the same closed city, Arzamas-16, as VNIIEF, one of Russia's two leading nuclear weapon design institutes and one which plays a major role in the laboratory-to-laboratory warhead transparency programme. In the USA, a similar centre could be established at the DAF complex.

Synergies between warhead transparency and downsizing of the Russian complex

Downsizing of the Russian nuclear weapon complex could have profound implications for a future transparency regime. A possible first step in studying this issue would be to initiate a laboratory-to-laboratory project—possibly as a part of the joint Minatom–DOE conversion study that was initiated in 2000—to develop an optimal configuration of the future complex that takes into consideration Russia's arms control commitments.

Monitoring the closure or conversion of excess warhead production capacity and non-production of new warheads

Monitoring the closure or converted status of the Avangard and Start complexes in Russia would help to address US concerns regarding the asymmetry in production capacities. In turn, Russia could verify non-production at the DAF complex at the Nevada Test Site. A first step could be a laboratory-to-laboratory study of possible non-production transparency methods at a former warhead assembly plant.

VII. Conclusions

Measures to confirm the elimination of nuclear warheads and the irreversibility of nuclear stockpile reductions are expected to become an important element of future nuclear arms reduction initiatives. As discussed elsewhere in this volume, warhead dismantlement transparency measures would probably be initially implemented on a bilateral basis in Russia and the USA and apply to narrow classes of nuclear warheads. Eventually, warhead dismantlement transparency would be expanded to cover broader portions of the nuclear stockpiles and involve the other nuclear weapon states. It could also be integrated with other transparency initiatives, including data exchanges, monitoring of new warhead production and controls on fissile materials.

However, significant breakthroughs in the area of warhead dismantlement transparency would require favourable political conditions, mutual trust, the development of and access to new technologies and implementation protocols, and the ability of the participating states to apply transparency measures to their nuclear weapon facilities and programmes. The downsizing and consolidation of the cold war nuclear warhead production infrastructures could provide important opportunities for introducing transparency initiatives.

10. Monitoring and verifying the storage and disposition of fissile materials and the closure of nuclear facilities

Annette Schaper

I. Introduction

This chapter examines transparency in the process of the dismantlement of nuclear warheads and the resulting release of excess plutonium and highly enriched uranium (HEU). In order to reduce the risk of nuclear proliferation, these materials must be disposed of. There are various plans for the disposition of plutonium and HEU. HEU can be diluted with depleted uranium in order to obtain low-enriched uranium (LEU), which is not weapon-usable unless it is re-enriched. Two methods for the disposition of plutonium are being studied, primarily by the United States and to some extent by Russia: (*a*) vitrification together with high-level waste, and (*b*) fabrication to uranium–plutonium mixed oxide (MOX) fuel, with subsequent irradiation in nuclear reactors.[1] Before these methods can be applied, the fissile material is put into intermediate storage. The verification task is to ensure that the material is not re-used for military purposes.

The total amount of military plutonium worldwide has been estimated at about 250 tonnes and the amount of military HEU at about 1700 tonnes.[2] Some of this material has been declared excess to military needs by Russia and the USA—about 50 tonnes of plutonium for each country, and 500 tonnes of

[1] A number of influential studies of the disposition of weapon-usable plutonium have been carried out. See, e.g., US National Academy of Sciences (NAS), Committee on International Security and Arms Control (CISAC), *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994); and NAS/CISAC, *Management and Disposition of Excess Weapons Plutonium: Reactor Related Options* (National Academy Press: Washington, DC, 1995). A French–German–Russian project for the building of a MOX pilot plant for Russian weapon-grade plutonium and the 1993 Russian–US HEU Agreement are among the most advanced projects. See Gesellschaft für Anlagen- und Reaktorsicherheit mbH, Siemens Aktiengesellschaft and Russian Ministry of Atomic Energy (Minatom), *Basisauslegung für eine Pilotanlage zur Produktion von Uran-Plutonium-Brennstoff aus waffengrädigem Plutonium und zum Einsatz dieses Brennstoffs in Kernreaktoren* [Principal design of a pilot plant for the production of uranium–plutonium fuel from weapon-grade plutonium and for the use of this fuel in nuclear reactors], Final report, 28 Feb. 1997; and Bunn, M., *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Carnegie Endowment for International Peace: Washington, DC, and Harvard University: Cambridge, Mass., 2000), available at URL <http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>.

[2] Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997); and the Internet site of the Institute for Science and International Security (ISIS: Washington, DC), URL <http://www.isis-online.org>.

Russian and 174 tonnes of US HEU.[3] Only a few tonnes of US material have been placed under International Atomic Energy Agency (IAEA) safeguards.

There is a lack of transparency in military fissile materials. Although substantial quantities of fissile material are considered excess to military needs, only a small amount is under international monitoring.

II. Steps towards greater transparency in fissile materials

The major sources of proliferation-relevant material and technologies are in the nuclear weapon states (NWS). Although they apply national controls, these states are not obligated to adhere to international standards and the security of their nuclear materials does not have to be monitored by an international agency. Proliferation risks have increased substantially since the end of the cold war because of the large quantities of fissile materials excess to military requirements, as have the risks of the diversion of fissile material in warhead dismantlement and material transport, storage and disposition processes. The dangers are particularly acute in Russia, which is in the process of transforming its nuclear control system. The security of the Russian nuclear production complex is believed to be far below Western standards and is in danger of deteriorating even further, exacerbating the risk of the proliferation of sensitive material and technologies.[4] All these factors contribute to the urgency of devising appropriate control measures.

The safeguards agreements between the non-nuclear weapon states (NNWS) and the IAEA have greatly reduced the danger of nuclear proliferation.[5] They have introduced high standards for facility and material protection, control and accounting (MPC&A). The lack of similar standards in the NWS poses major dangers. Universal international safeguards would promote both a security culture and high standards and should therefore be a long-term goal of nuclear arms control.

IAEA full-scope safeguards on nuclear materials in the NNWS, in all their nuclear activities, are key mechanisms for verifying compliance with the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT). In conformity with the 1971 NPT Model Safeguards Agreement, full-

[3] ISIS Internet site (note 2). The 174 tonnes of US HEU correspond to 100 tonnes of weapon-grade uranium equivalent.

[4] Potter, W. C., 'Before the deluge? assessing the threat of nuclear leakage from the post-Soviet states', *Arms Control Today*, vol. 25, no. 7 (Oct. 1995), pp. 9–16; Schaper, A., 'Nuclear smuggling in Europe—real dangers and enigmatic deceptions', eds V. Kouzminov, M. Martellini and R. Santesso, *Proceedings of the International Forum on Illegal Nuclear Traffic: Risks, Safeguards and Countermeasures*, UNESCO Science for Peace Series, vol. 4: *Illegal Nuclear Traffic: Risks, Safe-guards and Countermeasures* (UNESCO: Venice, 1998); and Orlov, V. A., 'Accounting, control, and physical protection of fissile materials and nuclear weapons in the Russian Federation: current situation and main concerns', Paper presented at the International Seminar on Material Protection Control and Accounting in Russia and the Newly Independent States, sponsored by the Deutsche Gesellschaft für Auswärtige Politik, Bonn, 7–8 Apr. 1997.

[5] Under the NPT (as well as the 1967 Treaty of Tlatelolco, the 1985 Treaty of Rarotonga, the 1995 Treaty of Bangkok and the 1996 Treaty of Pelindaba), the NNWS must accept IAEA safeguards to demonstrate the fulfilment of their obligation not to manufacture nuclear weapons.

scope safeguards—also referred to as INFCIRC/153-type safeguards—are designed to create assurances that material is not being diverted.[6] The principal method used is comprehensive material accountancy, complemented by surveillance and control techniques. In 1997 the IAEA member states adopted new safeguards arrangements in the Model Additional Safeguards Protocol (INFCIRC/540) to strengthen and improve the efficiency of the safeguards system.[7] While traditional IAEA safeguards aimed to ensure that illegal diversion of materials at declared facilities had not taken place, the strengthened safeguards aim to facilitate the IAEA's detection of undeclared activities at an early stage. The measures apply not only to potential recipient NNWS but also to potential supplier states, which include the NWS.

There is also a trend towards internationalization of the control and security of nuclear material in the NWS.[8] Several statements of intent have been made, for example, the declaration of the Group of Eight (G8) industrialized nations at the 1996 Nuclear Safety and Security Summit: 'We pledge our support for efforts to ensure that all sensitive nuclear material (separated plutonium and highly enriched uranium) designated as not intended for use for meeting defence requirements is safely stored, protected and placed under IAEA safeguards . . . as soon as it is practicable to do so'.[9] The Guidelines for the Management of Plutonium, which were agreed between the most important plutonium-using states in 1997 and incorporated in INFCIRC/549, state that: 'These guidelines apply to the management of all plutonium in all peaceful nuclear activities, and to other plutonium after it has been designated by the Government concerned as no longer required for defence purposes'.[10] An objective of the guidelines is to create maximum transparency. The NWS also made a commitment to increase transparency in excess fissile material at the 2000 NPT Review Conference: 'We are committed to placing as soon as practicable fissile materials designated by each of us as no longer required for defence purposes under the International Atomic Energy Agency (IAEA) or other relevant international verification'.[11] The Council of the European Union made a similar statement at this review conference.[12]

[6] IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), INFCIRC/153 (Corrected), June 1972, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>.

[7] IAEA, Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540, Sep. 1997, and subsequent corrections, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Numbers/nr501-550.shtml>.

[8] Schaper, A., 'The case for universal full-scope safeguards on nuclear material', *Nonproliferation Review*, vol. 5, no. 2 (winter 1998), p. 69, URL <http://cns.miis.edu/pubs/npr/vol05/52/schape52.pdf>.

[9] Moscow Nuclear Safety and Security Summit Declaration, 20 Apr. 1996, para. 25, available at URL <http://www.g7.utoronto.ca/g7/summit/1996moscow/declaration.html>.

[10] IAEA, Communication Received from Certain Member States Concerning Their Policies Regarding the Management of Plutonium, IAEA document INFCIRC/549, 18 Mar. 1998, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Numbers/nr501-550.shtml>. The guidelines are included as an attachment to the communications from states to the IAEA.

[11] Letter dated 1 May 2000 from the representatives of France, the People's Republic of China, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland and the United States of America addressed to the President of the 2000 Review Conference of the Parties to the Treaty on the

The goal of universal international safeguards may seem unrealistic but it could be approached in discrete steps, each of which is a transparency-promoting measure. Several such steps are already being implemented or seriously considered, as described in the sections below.

The IAEA Strengthened Safeguards

The IAEA safeguards reform of 1997—embodied in INFCIRC/540 and known as the Strengthened Safeguards System[13]—constitutes a qualitatively new approach to monitoring and controlling fissile material.[14] It marked an important change in the philosophy of the IAEA safeguards regime. The revelations in the early 1990s of Iraq's clandestine nuclear weapon programme had exposed a number of important shortcomings in that regime.

The Additional Safeguards Protocol in INFCIRC/540 primarily addresses the completeness of states' declarations with the aim of ensuring the absence of undeclared nuclear material and activities. It gives IAEA inspectors the right to obtain from the parties to the Protocol more information than was previously required about all the parts of their nuclear fuel cycles, from uranium mines to nuclear waste. It also grants them more intrusive physical access to locations subject to safeguards as well as complementary access to undeclared sites. In addition, inspectors have stronger authority to use new verification techniques, such as collecting environmental samples for laboratory analysis, for the purpose of assisting the IAEA in drawing conclusions about the presence or absence of undeclared nuclear material or nuclear activities at a specific location.

Under the Additional Protocol, states are required to submit 'expanded declarations' on nuclear fuel cycle technologies such as centrifuge enrichment technology. Exports and imports of such technologies must also be declared, as well as ongoing research activities. The IAEA has established a computerized system for the storage and retrieval of safeguards-relevant information from open

Non-Proliferation of Nuclear Weapons, NPT/Conf.2000/21, URL <http://disarmament.un.org/wmd/npt/2000doclist.htm#Documents>.

[12] European Union, 'Council common position of 13 Apr. 2000 relating to the 2000 Review Conference of the Parties to the Treaty on the Non-proliferation of Nuclear Weapons', *Official Journal L 97*, 19 Apr. 2000, Document 400X0297, Article 2 (2i), available at URL <http://europa.eu.int/eur-lex/en/archive/2000/l_09720000419en.html>.

[13] See note 7. This reform was previously called 'Programme 93 + 2'. The programme was launched in 1993 to strengthen the effectiveness and improve the quality of IAEA safeguards and was to present recommendations within 2 years. Although the consultations between governments and the IAEA were not completed in 2 years, the programme was supported by the 1995 NPT Review and Extension Conference. See Zarimpas, N., 'Nuclear verification: the IAEA strengthened safeguards system', *SIPRI Yearbook 2000: Armaments, Disarmaments and International Security* (Oxford University Press: Oxford, 2000), pp. 496–508; and 'Strengthening of International Atomic Energy Agency safeguards', [n.d.], *Australian Peace and Disarmament Newsletter* (Department of Foreign Affairs and Trade), URL <http://www.dfat.gov.au/isecurity/pd/947/947_11.html>.

[14] Progress in applying the strengthened safeguards has been slow. As of 2 Dec. 2002, Additional Protocols to IAEA safeguards agreements were in force for 28 states. IAEA, 'Strengthened Safeguards System: status of Additional Protocols', URL <http://www.iaea.org/worldatom/Programmes/Safeguards/sg_protocol.shtml>.

sources in order to facilitate its interpretation of the expanded declarations and to help build state proliferation or non-proliferation profiles.

The IAEA is to negotiate Additional Protocols with the NWS, which will lead to the implementation of selective measures in their civilian nuclear facilities. All the NWS have presented papers on how these measures can be implemented, but they differ in the degree to which greater transparency is accepted.[15] The new measures have not been entirely integrated into the existing safeguards system. Its success will depend on the willingness of states to offer increased transparency in their civilian nuclear complexes. Although the measures that the NWS will implement are quite modest, the reform must be seen as an important first step that acknowledges the need for universal safeguards application.

The Trilateral Initiative

Another positive step towards introducing nuclear controls in the NWS is the 1996 IAEA–Russian–US Trilateral Initiative. The objective of the Trilateral Initiative is to create assurances that steps taken in conjunction with the reduction of nuclear arsenals are irreversible.[16] When it is implemented, this initiative will constitute major progress towards the establishment of enhanced transparency in fissile materials. Special technical provisions are being developed that will allow the NWS to submit dismantled nuclear weapon components or other classified forms of fissile material to verification without giving IAEA inspectors access to information on the design or manufacture of the weapons. This calls for security arrangements for access and inspections that are very different from those applied in the NNWS. Since 1998, substantial progress has been made in developing and testing verification equipment. This is an important step towards the goal of introducing full-scope safeguards in the NWS. It will grant the IAEA an unprecedented role and might also trigger additional efforts to redesign and convert facilities to types that are more suitable for safeguards operations.

A Fissile Material Cut-off Treaty

A multilateral Fissile Material Cut-off Treaty (FMCT) would facilitate the application of safeguards, or at least the rudiments of safeguards, in the NWS.[17]

[15] These papers have not been published but have been presented to several governments. The papers of China and Russia were the least positive towards enhanced transparency in civilian nuclear facilities.

[16] IAEA, 'IAEA verification of weapon-origin fissile material in the Russian Federation and the United States', IAEA General Conference, Press Release PR 99/10, 27 Sep. 1999, URL <http:///www.iaea.or.at/GC/gc43/gc_pr/gcpr9910.html>; and Shea, T., 'Verification of weapon-origin fissile material in the Russian Federation and the United States', *IAEA Bulletin*, vol. 41, no. 4 (1999), p. 36, available at URL <http://www.iaea.org/worldatom/Periodicals/Bulletin/Bull414/article7.pdf>. See also chapter 11 in this volume on possible future roles for the IAEA.

[17] The term Fissile Material Cut-off Treaty is used in this chapter because it is the most commonly used term. This does not imply any recommendation as to the scope of the treaty, which is contested in the Conference on Disarmament. See, e.g., Johnson, R., 'FMT: breakthrough at last at the CD', Sep. 1998, URL <http://www.acronym.org.uk/fmctaug.htm>. See also Schaper, A., *A Treaty on the Cutoff of Fissile*

The fact that this treaty has been on the agenda of the Conference on Disarmament (CD) for several years with little progress is not directly related to matters of substance. While the FMCT has become an important symbol for nuclear disarmament efforts, its most important benefit would be to introduce verification measures in the NWS in order to ensure that they are not producing or diverting fissile materials for military purposes. This is similar to the verification task of the IAEA in the NNWS under the NPT. The principal difference under an FMCT verification regime would be that the NNWS would not be allowed to possess unsafeguarded materials from past production, while the NWS might eventually be allowed a 'black box' of materials previously excluded from safeguards. It is not clear whether the treaty will cover only the future production of weapon-usable materials or if it will also include previously produced materials. Even if the treaty is limited to a ban on future production, it is essential to ensure that material is not falsely declared as past production. If civilian material is excluded, it could eventually be declared as past production and diverted to military use. Ideally, all civilian and military fissile material produced after the entry into force of an FMCT should be placed under safeguards.

Many different types of facilities and measures may be appropriate for inclusion in the verification regime, and a range of different materials should be considered in negotiations. Plutonium and HEU can be directly used for nuclear weapons, while other materials first need to undergo technical processes. For example, LEU must be further enriched. Different materials have different technical thresholds that must be crossed if they are to be used in nuclear weapons. Accordingly, the current scope of IAEA safeguards in the NNWS varies, and a future FMCT verification regime would have to allow for such variation. Decisions will have to be made as to which facilities and materials should be included in the regime.

In a minimalist, or 'focused', approach, only facilities for reprocessing and enrichment (i.e., those producing unirradiated plutonium or HEU) would be included in the regime. Reactors would not be included, and verification of enrichment plants producing only LEU would be limited to verification of their design in order to create assurances that HEU is not being produced. In this approach, verification would end with the irradiation of the material. The level of irradiation at which verification would cease would therefore have to be specified. However, after the termination of verification, a large portion of the original amount of plutonium or HEU would remain in the spent fuel and could be easily recovered through reprocessing. The verification method that creates the highest assurance that material is not diverted is material accountancy. If verification is terminated too early, comprehensive material accountancy is not

Material for Nuclear Weapons: *What to Cover? How to Verify?,* PRIF Reports no. 48 (Peace Research Institute Frankfurt (PRIF): Frankfurt, July 1997), available at URL <http://hsfk.de/downloads/prifrep48.pdf>; and Schaper, A., *Principles of the Verification for a Future Fissile Material Cutoff Treaty (FMCT)*, PRIF Reports no. 58 (PRIF: Frankfurt, Mar. 2001), URL <http://hsfk.de/downloads/prif58.pdf>.

possible and clandestine production at declared facilities could not be detected. The verification envisaged in this scenario is therefore not credible.

In a more credible approach, both reprocessing and HEU enrichment plants and nuclear reactors would be included in the regime, as would spent fuel from reactors since it contains plutonium. It would therefore be possible to detect clandestine production through the verification process. However, opposition to this proposal has been voiced on the ground that the costs would be high. On-site inspections are the most expensive part of verification, and frequent, regular visits to all light-water reactors would be costly. For example, if all the reactors in the NWS were inspected with the same frequency as those in the NNWS, the IAEA budget would have to be increased substantially.[18] The feasibility of a random inspection regime should therefore be considered. Depending on the technical characteristics of a reactor, different probabilities of detection within a certain time interval could be assigned, and inspections could take place at different frequencies. This arrangement would reduce the costs and still provide a relatively high probability of detection. Material accountancy based on reports of all spent fuel produced after the entry into force of an FMCT could be established by the verification authority and applied at every step until the defined termination point of verification. Material accountancy would have to be implemented nationally, by each state. The de facto NWS (India, Israel and Pakistan) would be obliged to submit information to the verification body.

A more comprehensive approach would incorporate material accountancy in the LEU-producing enrichment plants. The advantage would be a full accountancy of all uranium. The assurance against undeclared HEU production in a declared enrichment facility would be higher than that provided by the other approaches, and verification of the material balances at reactors could be completed because material accountancy would cover the entire output, not only that from reactors.

The need for comprehensive verification does not seem to be shared by all of the NWS, but even a modest scheme would set precedents and create an important basis for further changes. Verification at former production facilities would constitute a major milestone, and the experiences gained would build the confidence needed to implement additional measures. Proceeding with negotiations on an FMCT is therefore an urgent priority.

The Plutonium Management and Disposition Agreement

Under the 2000 Plutonium Management and Disposition Agreement (PMDA), Russia and the USA would each be committed to dispose of 34 tonnes of

[18] As of 31 Dec. 2001 there were 236 power reactors under IAEA safeguards, out of a total of 438 nuclear power plants worldwide. IAEA, *Annual Report 2001,* Table III, Facilities under Agency safeguards or containing safeguarded material on 31 December 2001, URL <http://www.iaea.org/worldatom/Documents/Anrep/Anrep2001/table_3.pdf>; and IAEA, 'Latest news related to PRIS [Power Reactor Information System] and the status of nuclear power plants', 1 Jan. 2002, URL <http://www.iaea.org/cgi-bin/db.page.pl/pris.main.htm>.

weapon-grade plutonium,[19] using the methods of irradiation in reactors, immobilization or any other method agreed by the parties. The PMDA regulates the quantities to be disposed of annually and calls for the development of an action plan for implementing technologies and accelerating the rate of disposition. In addition, it addresses cooperation with and assistance from other states, safety and security aspects, international financing and verification. The PMDA is important because it will be the first legally binding agreement on the disposition of weapon-origin plutonium. It therefore sets a precedent for further disarmament agreements and verification measures, including agreements between other NWS.

The PMDA verification provisions are disappointing, however, because they do not reflect the signatories' commitments to international transparency and IAEA verification and because the agreement is only bilateral. Article VII.3 states that 'Each Party shall begin consultations with the . . . IAEA at an early date and undertake all other necessary steps to conclude appropriate agreements with the IAEA to allow it to implement verification measures'. This formulation does not impose a strong obligation on the parties, and there is a risk that the IAEA might never be involved. Moreover, there is no mention of the Trilateral Initiative. The international community should urge both states to draw up a specific timetable for when and how the IAEA will be involved in verification of the PMDA and how to build on the progress made by the Trilateral Initiative.

The goal of verification in the PMDA is simply to establish assurances that technical measures are being implemented as agreed. The agreement does not even mention the fact that transparency in nuclear disarmament is in the interest of the international community, even though it calls for assistance from other states. It should also stipulate that the parties must report on progress in their disposition of plutonium to ensure at least a degree of international transparency.

Large sections of the PMDA are devoted to the protection of sensitive information. The agreement mentions the use of information barriers during inspections and defines categories of sensitive information. In order to conceal the isotopic composition of excess plutonium, which is still regarded as secret, the agreement explains how excess plutonium may be diluted with 'blend stock' plutonium of a different isotopic composition, so that information about the original plutonium composition will not be revealed. This means that the quantity of plutonium to be disposed of will in fact be greater. Although these provisions for secrecy may be criticized as excessive, the decision to follow such a complicated procedure shows goodwill. On the one hand, the requirement for secrecy in the application of verification measures by the NWS must be respected if these states are to be expected to collaborate. On the other hand, they should be urged to accept, in principle, the need to advance transparency

[19] The US–Russian Agreement concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, 1 Sep. 2000, available at URL <http://www.ransac.org/new-web-site/related/agree/bilat/pudisp-agree.html>. The PMDA had not entered into force as of Dec. 2002.

and move forward towards a universal verification system for all civilian fissile materials, including excess military materials.

III. Verifying the disposition of nuclear material

Pit storage

When warheads are dismantled, their fissile components—plutonium and HEU—are released in the form of pits. If these pits were further processed to convert the material they contain into oxide bulk forms, the disarmament process would become irreversible. However, Russia and the USA appear to be planning to place pits in intermediate storage, leaving at least part of the inventory intact. Since pits are countable items, such a storage procedure would have the advantage of facilitating verification at this stage.

The task of verification would be to ensure that real pits, not decoys, enter the storage plant. Because pits bear highly sensitive information, NWS will not allow them to be inspected. They must therefore be delivered to storage plants in sealed containers. It must be guaranteed that each container holds a pit and that each seal remains intact and is unambiguously identifiable.

There are various methods for applying seals, some of which are not costly. Many methods are being used or developed by the IAEA and the European Atomic Energy Community (Euratom). One is a forgery-proof method using fiber-optic seal tecnology. This would allow a pit storage facility to be monitored externally to account for every pit that enters or leaves for further processing.[20]

The NWS have carried out much technical work on such aspects of verification. However, although Russia and the USA have been engaged in technological cooperation on the verification of nuclear warhead dismantlement since 1995, the results of this cooperation have not been published.[21]

Processing of bulk material

All the options for material disposition that have been seriously considered so far—dilution of HEU with natural or depleted uranium, fabrication of MOX

[20] IAEA, *Safeguards Techniques and Equipment*, International Nuclear Verification Series no. 1 (IAEA: Vienna, 1995); Japan Atomic Energy Research Institute (JAERI), 'Research on safeguards technology', URL <http://inisjp.tokai.jaeri.go.jp/ACT95E/menu195.htm>; and Zheng, Y. T. *et al.*, 'The study of fiber-optic seal technology for arms control', Paper presented at the 8th International Summer Symposium on Science and World Affairs, Beijing, 23–31 July 1996.

[21] The principal partners in the Russian–US cooperation are the All-Russian Scientific Research Institute of Technical Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF) in Chelyabinsk-70 and the US Sandia National Laboratories. The Russian laboratory was previously responsible for research and development of new nuclear weapons. Rubanenko, N. F., 'Nuclear weapons' transparent dismantlement', Paper presented at the International Pugwash Workshop, Snezhinsk, Russia, 11–13 Sep. 1997. See also chapters 5 and 9 and appendix 8A in this volume. A conference volume containing *c.* 50 contributions presented at a conference of both research institutes held on 18–22 Aug. 1997 has been made available only to the Russian and US governments.

fuel from plutonium and irradiation in reactors, and vitrification of plutonium with high-level waste—involve bulk material. Countable items, such as sealed containers with pits, would enter a facility, and some sort of bulk material, probably oxide powders of uranium and plutonium with various isotopic compositions and mixtures, would leave it for further processing.[22] Some additional bulk material would probably also enter the facility as blend stock for dilution in order to change the isotopic composition of the pits, which remains highly classified information. Only rough estimates could be made of the amounts of fissile material that enter the facility because the mass of the pits would remain unknown. Processes inside the facility could not be monitored because, again, sensitive information would be revealed.

Nevertheless, it is possible to verify fairly precisely the quantities and isotopic compositions of all materials leaving a facility. Methods for this purpose have been developed and tested by the IAEA and Euratom.[23] Reprocessing, enrichment and fuel fabrication (uranium and MOX) plants are examples of nuclear cycle facilities that handle bulk material. Nuclear reactors, in contrast, contain only fuel elements, which are countable and therefore much easier to verify.

The basic approach to verification in bulk-handling facilities—such as MOX fabrication, reprocessing or vitrification facilities—is material accountancy, which verifies a detailed report by the owners, supplemented by containment and surveillance techniques. Normally, flows are measured at predetermined locations known as 'key measurement points' and samples are taken from various areas. Because some of the process flows might contain highly radioactive materials (e.g., when mixed with high-level waste), measurements take place behind radiation shielding and direct access is difficult. Extensive shielding and radiation protection measures make it more difficult to maintain an overview of all the potential diversion risks. The total content of fissile materials must be established to the extent possible through various measurements (e.g., mass of flows, isotopic compositions of samples and material accountancy of inputs). During the industrial process, nuclear materials used as feedstock may be changed isotopically, chemically and physically. Furthermore, some nuclear materials would become waste products, and minute quantities would be discarded in waste water or otherwise discharged. A common objective from the standpoint of both verification and financial considerations would be to keep the wastes and losses at the lowest possible levels and to maintain precise material accounts. If the material comes from unverified storage sites, the quantities involved must be measured independently. The output of fuel cycle plants consists of countable items, which are easier to verify.

[22] E.g., in the French–German–Russian project on plutonium disposition, the French–Russian contribution will be the fabrication of feedstock containing 30% plutonium oxide and 70% uranium oxide. The German–Russian contribution will be the fabrication of MOX from this feedstock. See note 1.

[23] Shea, T., 'On the application of IAEA safeguards to plutonium and highly enriched uranium from military inventories', *Science & Global Security*, vol. 3, nos 3–4 (1993), p. 223.

There are technical problems that would cause uncertainties in results. Errors in calculated plutonium content must be expected. They may stem from biases in solution measurements, time delays in sample analyses or measurement limitations owing to radioactivity. Similarly, the precision of material accountancy in civilian bulk-handling plants, especially reprocessing and enrichment plants, is limited. The limits are dependent on the thoroughness of safeguards, a fact which has a direct bearing on safeguards costs.

In the NNWS, implementation of safeguards is taken into account in the planning stage of a plant; verification of plant design can take place during construction.[24] This makes it much more difficult to pursue unmonitored diversion. Similarly, because plants for the disposition of excess weapon material have not yet been constructed, it would be possible to design and build them in a way that facilitates the implementation of international safeguards according to IAEA standards.

Verification as thorough as that described above would probably be applied only to facilities which do not handle fuel with the original pit isotopic composition. This means that material accountancy is likely to start after the material obtained from the dissolution of pits has been mixed with blend stock. However, an external monitoring regime for such 'black box' facilities should be put in place in order to obtain an account of the number of warheads and pits being destroyed and a rough estimate of the expected quantities of fissile materials. It is also recommended that the authorities in the NWS which are responsible for the facilities publish information on the average masses and average isotopic compositions of the pits in order to enhance the precision of such estimates. Such data would not reveal information that is proliferation-relevant but they would be beneficial for transparency.[25]

Reactor fuel and material for final disposal

Items leaving material disposition facilities would be either fresh fuel elements (LEU or MOX) or vitrified waste. The latter would be intermediately stored until it entered a final disposal site. Under the classic INFCIRC/153-type IAEA safeguards, the safeguards ceased when the material was practicably irrecoverable. Even after the 1997 safeguards reform, however, states are still required

[24] An example is the safeguards system at the new MOX plant at Hanau, Germany, that was developed before the plant was built. This plant never began operation, but there are plans to use its interior design in the French–German–Russian project for the building of a MOX pilot plant for Russian plutonium from dismantled warheads. See note 1.

[25] In the USA, the isotopic composition is classified as long as the material is in warhead component form. As soon as this form is modified, the masses and isotopic composition can be revealed. See Markin, J. T. and Stanbro, W. D., 'Policy and technical issues for international safeguards in nuclear weapon states', *International Nuclear Safeguards 1994,* vol. 2, Proceedings of the Symposium on International Safeguards, Vienna, 14–18 Mar. 1994, p. 639. See also US Department of Energy, Office of Declassification, 'Restricted data declassification decisions, 1946 to the present', RDD-7, 1 Jan. 2001, URL <http://www.fas.org/sgp/othergov/doe/rdd-7.html>. This document contains over 100 pages of technical details which are now declassified. In Russia, the isotopic composition of disarmament materials remains classified.

to submit information on material processed for final disposal. This requirement should also apply to the NWS, especially with regard to the disposal of material from nuclear disarmament.

Fuel elements would first enter a storage site and then be used in a reactor. It should be agreed internationally that, once material has been subjected to safeguards, it can no longer be removed, thus constituting an irreversible step. This implies that reactors using fuel made from disposition materials should be submitted to IAEA safeguards, as in the case of reactors in the NNWS. Because fresh and spent fuel elements are countable items, verification is much easier and cheaper than verification in bulk-handling facilities.

The verification goal at reactors is to provide assurance that there is no diversion of fresh or spent fuel.[26] Depending on the type of reactor, fresh fuel may consist of LEU, MOX, HEU or natural uranium. IAEA material accountancy and verification of fresh fuel are carried out by item counting and identification, non-destructive measurement and examination to verify the continued integrity of the item, assuming that the fuel has been received from an IAEA-safeguarded facility. However, when fresh MOX or HEU fuel originates from unsafeguarded facilities, additional measurements must be performed and the fuel must be maintained under seal or surveillance. Consequently, seal verification and/or surveillance evaluation must also take place.

Similarly, the fuel in the reactor core must be verified. The methods may include item counting and serial number identification after refuelling has been carried out, but before the reactor vessel is closed. Under INFCIRC/153-type safeguards, inspectors are required to be present at all refuelling operations. An evaluation should be made of whether the overall number of inspections could be reduced by making some of them unannounced random inspections or by automating the monitoring and surveillance of fuel reloading and the resulting unchanged state of the core. The spent fuel pond must also be verified by, for example, observation, measurements of the Cherenkov radiation (a physical effect owing to radioactive decay under water) or surveillance of the sealed transfer gate.

Methods of verification

Containment and surveillance

The technical component of verification is the so-called containment and surveillance technologies. The equipment that the inspecting authorities will install in facilities includes seals, detectors, monitors and cameras to record any activity occurring in a particular area of a nuclear installation. It will allow the detection of undeclared movements of nuclear material and potential tampering with containment and/or surveillance devices. In light-water reactors, for

[26] Harms, N. and Rodriguez, P., 'Safeguards at light-water reactors: current practices, future directions', *IAEA Bulletin*, vol. 38, no. 4 (1996), URL <http://www.iaea.org/worldatom/Periodicals/Bulletin/Bull384/harms.html>.

example, cores are usually not opened more than once per year, so it is often possible to seal the head of the reactor's pressure vessel. The more sophisticated and automated an instalment is, the fewer on-site inspections would be needed to provide the same level of assurance that material has not been diverted. Automated data transfers to a verification agency would further reduce the need for on-site inspections.

Inspections

Verification is completed by inspections. Their purpose is to examine the operational status of a plant and the installed containment and surveillance equipment. In addition, verification of material accountancy is of particular importance. Physical inventories and streams of nuclear materials must be confirmed. The methods used to achieve the inspection goals depend primarily on the type of the facility and could include combinations of: (*a*) observations, measurements and tests to determine whether the design information is correct; (*b*) installation of containment and surveillance technologies; (*c*) installation of detection technologies for proscribed activities; (*d*) auditing of accounting records and comparison with reports submitted to the IAEA; (*e*) accountancy measurements (e.g. of the volume, concentration and enrichment of nuclear materials in streams), tracking the movement of solutions and taking samples in the case of bulk facilities (if material is in the form of countable items, such as those in a reactor, they must be counted, identified and examined by non-destructive means in order to verify their continued integrity); and (*f*) the taking of environmental samples as a means to detect additional undeclared operations.

Samples must be shipped to a laboratory for analysis—for example, in the case of international safeguards, to the IAEA Safeguards Analytical Laboratory in Seibersdorf, Austria. Measurement data taken from inspections and from laboratory analyses are used to establish an independent material accountancy which is compared with the operator's declaration.

INFCIRC/153 provides for ad hoc, routine and special inspections. Ad hoc inspections are conducted when an initial report must be verified or in the case of transfers. Routine inspections take place on a regular basis; the frequency of these inspections depends on the amount and kind of nuclear material in a facility. Special inspections take place only when the IAEA considers information to be inadequate. INFCIRC/540 allows access outside the nuclear sites, using the existing right of access at 'short notice' or 'no notice' during routine inspections. As a result of the formal definitions of the frequency of INFCIRC/153-type routine inspections, most inspections take place in power reactors and in states with large nuclear programmes where confidence in non-proliferation is already high, such as Canada, Germany and Japan. However, the costs for safeguards could be substantially reduced if routine inspections in reactors were to be replaced by a random system. The goal of verification is the deterrence of non-compliance by the risk of detection. The use of unannounced random inspections would contribute to this because the facility operator would need to be prepared for such inspections at any time. The absence of undeclared facility activities at the time of the inspection would provide assurance that there had been no such activities over the entire period since the last on-site inspection.

IV. Additional verification and transparency measures

The implementation of current and future disposition activities will be reinforced if the policy goal is global, transparent reduction. This could be achieved if the moratorium on the production of fissile materials for use in nuclear weapons that is currently observed by the NWS was codified in an FMCT. Although the CD has not started to negotiate a ban, some of the verification measures which are likely to be proposed are known. The crucial objective is the detection of undeclared activities. Another task would be verification of the closure of production facilities.

In the longer perspective, when progress has been made towards comprehensive nuclear disarmament, it will be important to pursue declarations of fissile material stockpiles, transparency measures and verification that undeclared materials no longer exist.

Detection of undeclared enrichment and reprocessing activities

Enrichment processes

The most important known enrichment processes are gas diffusion enrichment, gas centrifuge enrichment, jet nozzle enrichment, chemical enrichment, electromagnetic isotope separation (EMIS) and atomic vapour laser isotope separation (AVLIS).[27] Although it is unlikely that a new enrichment process will be developed, it would be impossible to conceal the clandestine use of such a process. Enrichment requires natural uranium or LEU as feedstock. If all the uranium in the world were to be accounted for through global transparency measures, its use for clandestine enrichment would be detected. A clandestine use would require the use of undetected stockpiles or the discovery of a new deposit. Thorough accountancy of uranium takes place in the NNWS and is verified by the IAEA. Unfortunately, similar safeguards do not exist in the NWS and in the non-parties to the NPT. However, there are other technical means for the detection of clandestine enrichment activities.

Most enrichment processes use the volatile chemical compound uranium hexafluoride (UF_6). Unless it is elaborately shielded, UF_6 can be detected by means of atmospheric measurements made adjacent to a plant or by laser imaging detection and ranging (LIDAR) techniques. LIDAR techniques examine laser light reflected by the atmosphere using spectral analysis methods and can iden-

[27] See, e.g., Federation of American Scientists, Special Weapons Primer: Weapons of Mass Destruction, ‘Uranium production’, [n.d.], URL <http://www.fas.org/nuke/intro/nuke/uranium.htm>.

tify traces of molecules. LIDAR can also be operated from satellites, but at present measurements are carried out by the national technical means (NTM) of some states.[28] There is no other application for UF_6 apart from enrichment. Atmospheric measurements can also detect whether HEU has been fabricated.

Some processes, in particular AVLIS and EMIS, do not use volatile materials and would be easier to conceal. However, EMIS would require large amounts of energy, which could be detected by means of infrared imagery, for example, from a satellite. (E.g., if Iraq's calutrons had been in operation, they would have been detected by NTM.) To hide the production of heat, an elaborate underground cooling system would have to be installed, which also requires a high level of energy, or the plant would have to be built as part of another facility. In the latter case, however, the ancillary systems would be visible. AVLIS is the enrichment method which would be the easiest to hide and extremely difficult to detect because it gives off little energy and releases no revealing gases. However, this process is the most sophisticated technically and could only be managed by a few industrialized states.[29] All enrichment processes leave traces of HEU, which are detectable in on-site inspections.

Reprocessing

The aim of reprocessing is the separation of plutonium and uranium from the radioactive fission products, which are all contained in spent nuclear fuel. The most effective and widely used process is plutonium and uranium recovery by chemical extraction. Initially, the spent fuel is crushed mechanically and then chemical separation processes are used. The central difference between an ordinary chemical factory and a reprocessing plant is the high level of radioactivity, which poses a danger for both the workers and the environment. Reprocessing plants must not only provide storage for fuel elements for years after removal from the reactor (so that most radioactive isotopes can decay) but also, and above all, implement extensive radiation protection measures.

Reprocessing releases several characteristic effluents that can be detected and monitored. They include particulate matter and gaseous fission products, which, to a greater or lesser degree, are radioactive, especially noble gases that cannot be bound chemically. Reprocessing produces far more emissions than the operation of a reactor or enrichment, and these emissions are likely to provide clear evidence of what is taking place. If detection is to be avoided, extremely sophisticated shielding measures are necessary in order to prevent the release of

[28] The USA has an extensive R&D programme to improve NTM, e.g., the Chemical Analysis by Laser Interrogation of Proliferation Effluents. Panofsky, W. K. H., Report of the Comprehensive Research and Development Review Committee for the US Department of Energy, Office of Nonproliferation and National Security, 8 June 1996.

[29] After many years of R&D, the building of a demonstration plant was begun in the USA but it was suspended in 1999. Lawrence Livermore National Laboratory, 'Advanced uranium enrichment project ends', News Release, 9 June 1999, URL <http://www.llnl.gov/llnl/06news/NewsReleases/1999/NR-99-06-05.html>. AVLIS will not be competitive and will not be used commercially. Knapik, M. and MacLachlan, A., 'USEC terminates AVLIS program, looks to silex, centrifuges; Richardson "surprised"', *Nuclear Fuel*, 14 June 1999.

revealing traces of radioactivity. Such traces can be distributed and detected over great distances.[30] Methods of detection include the taking of air samples or the use of LIDAR from aircraft or satellites. Shielding measures would only reduce, but not totally eliminate, the emissions and thus the risk of detection would remain.

Verifying the closure of facilities

If a state renounces the production of fissile materials for military purposes, the production facilities will be either closed down or converted to civilian use. Verifying that a facility is closed down is relatively simple because there are no operations. Traffic and movements can be detected by remote sensing. Inspectors can apply tags and seals to verify that the technical situation of a plant has not changed. Random, not necessarily frequent, inspections would deter cheating by creating the possibility that undeclared operations would be detected.

Warhead production facilities are a special case. Before intrusive inspections can take place, warhead dismantlement must have progressed so far that sensitive information can no longer be revealed. The remaining parts of the building that may still contain sensitive information can then be sealed. While inspectors can be banned from entering these parts of the building, they can inspect the seals to verify that such parts have not been accessed. Verification of operating civilian reprocessing and enrichment plants can be carried out with methods such as those described above.

A facility goes through several stages of operational status. When it is undergoing decommissioning, the frequency of inspections could be kept comparatively low, depending on whether operations could be resumed and on how much time would be needed to resume them. Inspections can often be replaced by the use of satellite imagery. In a fully decommissioned facility, the verification task is simpler. Theoretically, a stand-by facility can resume operations very quickly but, as long as it is not running, inspections are much easier than in an operating facility. In an operating facility, assurances must be provided, for example, that LEU enrichment facilities are not producing HEU and that the installations at reprocessing plants are operating as declared. The technical

[30] US Congress, Office of Technology Assessment (OTA), *Environmental Monitoring for Nuclear Safeguards,* OTA-BP-ISS-168 (US Government Printing Office: Washington, DC, Sep. 1995), available at URL <http://www.wws.princeton.edu/cgi-bin/byteserv.prl/~ota/disk1/1995/9518/9518.PDF>. Eight contributions to the Convention on Strengthened and More Cost Effective Safeguards of the IAEA Symposium on International Nuclear Safeguards, Session 7: Environmental Monitoring, Vienna, 13–17 Oct. 1997, are concerned with the measurement of radionuclines in the environment. The proceedings are available on CD-ROM from the IAEA. See also Nakleh, C. W. *et al.*, 'Noble-gas atmospheric monitoring for international safeguards at reprocessing facilities', *Science & Global Security*, vol. 6, no. 3 (1997), pp. 357–379; and Kalinowski, M. B. *et al.*, *Rückschließbarkeit auf Plutoniumabtrennungen durch Auswertung von Messungen des atmospärischen Krypton-85 in Wochenproben bei verschiedenen Abständen von der Wiederaufarbeitungsanlage Karlsruhe* [Identification of plutonium separation by analysis of measurements of atmospheric Krypton-85 in weekly samples obtained from the Karlsruhe Processing Plant], (Interdisziplinäre Arbeitsgruppe Naturwissenschaft, Technik und Sicherheit (IANUS): Darmstadt, Mar. 1998). A range of US R&D programmes are designed to improve the techniques; in 1996 they received $194.4 million in funding. See Panofsky (note 28).

methods of verification include the application of seals, temperature and other signal measurements and analysis of environmental samples. Analysis of plutonium samples collected at reprocessing plants provides an unambiguous indicator of the age of the sample.

Satellite imagery is a special verification tool.[31] Since 1999, a new generation of commercial satellites has been launched with 1-metre spatial resolution at visible wavelengths. This allows any construction and visible changes at nuclear sites to be monitored. For example, at an undeclared nuclear facility or a closed facility which had restarted operations, high-resolution imagery would show security installations such as fences and guards, thermal signatures from the use of energy, traffic and movements into and from storage sites, and power lines associated with the electricity generated by reactors. Images acquired over a long period of time could be used to assess the status of the facility.

Operating reactors and several kinds of uranium enrichment facilities produce energy and therefore need cooling. For the former, air, steam or water is used, and for the latter, sea, lake or river water is often used for cooling. When a facility is operating, the higher temperatures of the streams leaving it can be monitored with thermal infrared detectors. The US Landsat satellite sensor is capable of detecting temperature differences as small as 0.25° C. This allows conclusions to be drawn about the operational status of reactors and other production facilities.

Environmental monitoring is an effective tool for clarifying suspicions. Instruments have been developed to identify extremely small traces of materials.[32] Uranium and plutonium isotopes can be detected in quantities smaller than a nanogram. The isotopic composition of environmental traces can be analysed to reveal production histories, as can traces in the vicinity of a plant. Noble gases and particulate matter are released into the atmosphere while a plant is in operation. Sampling them is not particularly difficult; it would be sufficient to wipe a surface or collect traces in the vicinity of plants.

Wide-area environmental monitoring to detect undeclared facilities is much more problematic. Some materials can be carried long distances. Monitoring rivers is fairly easy, but monitoring atmospheric distribution would require many stations, since weather conditions affect the results. Many of these methods are currently being implemented or explored by the IAEA as part of its Strengthened Safeguards System. In the course of nuclear disarmament, it might become necessary to implement similar verification in the NWS as well. It is likely that the FMCT will be the first nuclear disarmament treaty to make use of such processes.

[31] Zhang, H. and von Hippel, F., 'Using commercial imaging satellites to detect the operation of plutonium-production reactors and gaseous-diffusion plants' *Science & Global Security*, vol. 8, no. 3 (2000), p. 261; and Jasani, B. *et al.*, 'Space-based monitoring of proliferation of weapons of mass destruction', *Proceedings of the ESARDA–INMM Workshop on Science and Modern Technology for Safeguards,* EUR 17264EN (European SAfeguards Research and Development Association (ESARDA), EU Joint Research Centre and Institute for Nuclear Materials Management (INMM): Ispra, 1996), p. 275.

[32] US Congress, Office of Technology Assessment (note 30).

Detection of undeclared materials

If comprehensive nuclear disarmament becomes a reality, verification will have to move beyond the approaches described in sections III and IV of this chapter. The possession and production of nuclear material outside international controls would then be banned. Verification must be able to detect, with sufficiently high probability, any illegal use and production of fissile materials. It must also be able to track and identify any undeclared material. This type of international verification is currently applied by the IAEA in the NNWS parties to the NPT. When the current NWS no longer possess nuclear weapons, the task will be much more difficult because of their long and complicated production histories and the decades in which there were no international controls.

An important parameter in the verification process would be the reconstruction of past production. It is possible to account for past production of fissile material by examining the physical evidence at reactors and enrichment facilities. Two technical methods of 'nuclear archaeology' have been described by Fetter.[33] The first technique uses the concentrations of long-lived radionuclides in permanent components of the reactor core to estimate the neutron flux in various regions of the reactor and thereby to verify declarations of plutonium production in that reactor. This method becomes complicated, however, when, instead of plutonium, tritium has been produced. An interpretation must therefore compare the results with the declarations and check for consistency. The second technique uses the ratio of uranium isotope concentrations in enrichment 'tails' to determine whether the uranium was used to produce LEU or HEU. These measurements must be compared to existing documentation and declarations. However, the tails must still be available for evaluation and the composition of the feed uranium must be known.

A prerequisite for nuclear archaeology techniques is complete openness regarding the production history of military fissile material. The task of verification then consists of confirming and re-recording measurement data with the aid of the documentation, in order to establish a book inventory that can be compared with the declarations. This procedure was followed in South Africa when its nuclear arsenal was dismantled. Furthermore, it is possible to draw conclusions regarding past production by using radiological measurements in nuclear plants that have been closed down or are still in operation. There will, however, be a higher rate of error in the determination of the initial stock than in anything in which the IAEA has previously been involved. For example, in the plutonium stockpile data published by the USA, there was a discrepancy of 2.8 tonnes between the measured and estimated stockpiles—an amount sufficient for the manufacture of about 1000 warheads.[34] This finding does not mean

[33] Fetter, S., 'Nuclear archaeology: verifying declarations of fissile-material production', *Science & Global Security*, vol. 3, nos 3–4 (1993), pp. 237–59.

[34] US Department of Energy (DOE), *Plutonium: The First 50 Years. United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994*, DOE/DP-0137, Feb. 1996, URL <http://www.etde.org/html/osti/opennet/document/pu50yrs/pu50y.html>; and Albright, Berkhout and Walker (note 2).

that the 2.8 tonnes had been hidden or otherwise diverted; the discrepancy could be explained by the fact that there were insufficient documentation and inaccurate measurements in the past. Errors in future figures emanating from other NWS are likely to be even higher. In the Soviet Union, for example, material accounting was based solely on documentation, not on measurements.[35] In the NNWS ,whose nuclear industry was subjected to international surveillance at an early stage, there are also measuring inaccuracies, although on a much smaller scale, and it is assumed that their declarations are correct.

Measurements on materials and plants should also be carried out. It must be accepted that there will always be discrepancies and inaccuracies. However, with enhanced transparency, the use of diverse sources of information and the possibility of challenge inspections, it is highly probable that undeclared material storage sites will be detected sooner or later. This would have the effect of deterring deception.

Societal verification

The large discrepancies that are likely to be revealed through verification procedures do not necessarily indicate deception. They need not even give rise to suspicion as long as there is confidence in societal verification, which can be added to the classic technical instruments of verification. In contrast to traditional verification concepts, societal verification relies on the participation of the entire population of a state and is not confined to highly specialized, technically well-equipped teams of experts. In principle, citizens are encouraged to report to a competent international authority any information on treaty violations or attempted treaty violations. This would be not only the right but also the duty of every citizen and would therefore have to be incorporated into state legislation. The reporting of information must, therefore, not be treated as a punishable offence, either as treason or any other crime, in the states concerned. This concept of involving the whole population is also known as 'Citizens' Reporting'.[36] In practice, informants will often be individuals who come to learn of secret projects because of their training as specialists, engineers or scientists. They must be allowed to disclose their information without incurring the risk of reprisal.

However, confidence in societal verification will be highly dependent on how democratic a state is. Mechanisms could be set up for offering protection to informants, ranging from the provision of legal support in conflicts over industrial law to the creation of an international relief fund, or even relocating and hiding informants. The former approach is more relevant for democratic states, the latter in states where basic human rights are not guaranteed.

[35] Roumyantsev, A. N., 'Establishing a SSAC [State System for Accounting and Control] in Russia: structural, organizational, budgetary and political problems', Paper presented at the Conference on Fissile Material Security in the CIS, Deutsche Gesellschaft für Auswärtige Politik, Bonn, 7–8 Apr. 1997.

[36] Rotblat, J., 'Societal verification', eds J. Rotblat, J. Steinberger and B. Udgaonkar, *A Nuclear-Weapon-Free World: Desirable? Feasible?* (Westview Press: Boulder, Colo., 1993), pp. 103–18.

All things considered, there is a good chance that fraud would be detected. If a party to a convention intends to cheat by withholding undeclared nuclear materials, extreme secrecy would have to be kept and maintenance staff would have to be carefully selected and controlled. Furthermore, indoctrination and intimidation, as well as the offering of rewards, would be needed to guarantee that employees and those who knew about the deception would not reveal the fraud. A 'technical myth' would have to be created to conceal the real nature of the activities. In this context it would have to be explained, for example, how the radioactivity in the samples came to be there. (The North Korean violation of the NPT was uncovered by inconsistencies between analysis results and North Korean explanations.) The deception would have to be coordinated between all participants, and personnel would have to be indoctrinated into believing as much of it as possible, although key employees would realize that they were violating national legislation.

If the international community became suspicious, a cheating state might refuse inspections, as occurred in both Iraq and North Korea, or it might use delaying tactics such as adjourned diplomatic negotiations in order to allow time for the removal of revealing clues, as occurred in Iraq. The more often observations of this kind are made, the stronger the suspicion becomes. This could then trigger additional, more intrusive verification methods, for example, interviews with staff at suspected plants and establishments.

V. Special issues

Sensitive information at nuclear weapon facilities and secret past activities

In former military facilities—reprocessing and enrichment plants or nuclear warhead maintenance and dismantlement facilities—verification could reveal sensitive information.

In some NWS, the isotopic composition of fissile materials is still regarded as highly classified information. Verification scenarios developed for the disposition of plutonium therefore include the use of blend stock in order to mask its isotopic composition. If the isotopic composition were to be revealed, an additional risk of proliferation danger would not be created because it is generally known that the NWS prefer a high plutonium-239 content for their weapon plutonium and a high uranium-235 content for their weapon uranium. There is room for speculation as to whether such secrecy is simply an unquestioned tradition or whether there would be surprising revelations, for instance, that the composition is of an embarrassingly poor quality or, on the other hand, that plutonium has been further enriched.[37]

It is possible that material pieces or tools that reveal the amounts used in nuclear weapon components could be found at production sites. This informa-

[37] In 1994 a smuggled sample of plutonium was intercepted in Tengen, Germany. It originated in Russia and apparently had been centrifuge-enriched with plutonium-239.

tion is regarded as being far too sensitive to be revealed. An urgent task at such a facility would therefore be the removal of such parts and tools as soon as possible in order to prepare it for the start of safeguards. This work is necessary in any event in order to minimize proliferation dangers.

Specially managed access arrangements to protect sensitive parts of a facility will still be necessary. This type of problem has been solved in France and the UK by the Euratom safeguards.[38] Euratom has verified activities at dual-use facilities as long as they were declared civilian. When the activities were declared to be military, Euratom ended its verification, as occurred at the Sellafield Nuclear Power Plant in the UK. At former military facilities that are now used for civilian production and at which sensitive information can still be found, verification and site inspections should be less intrusive and would need specially managed access provisions. As a consequence, material accountancy in the interior of such facilities might not be possible for a certain period. However, this period must be limited, declared and extended only as long as needed in order to remove the sensitive data. At former military facilities which are now closed and where there is still sensitive information, verification must use containment, surveillance and additional observation from the outside for a limited period. The question of how much managed access is possible in the event of strong suspicions remains to be investigated.

Facilities not designed for safeguards

Special technical verification problems are posed by facilities which were not designed to accommodate safeguards or equipped to facilitate sampling procedures. These facilities have not set up their measuring points with easy access, and it could be technically difficult to provide material balance areas. Records could have been kept very differently from the procedures used in the NNWS. In particular, facilities in the NWS did not need to make physical inventories for safeguards inspectors since those states were not required to accept international verification arrangements. It is much more difficult to install technical equipment in an existing facility than to prepare for installation when the facility is being designed and built.

Many problems need to be solved. Regulations should be implemented for technical, organizational and reporting requirements for material control and accountancy, measurement systems need to be set up and personnel should be trained.

[38] Chapter VII of the 1957 Euratom Treaty establishes safeguard agreements for EU member states. Euratom has an agreement with the IAEA for joint application of safeguards to verify that there is no diversion of nuclear materials to nuclear weapons or other nuclear explosives in any of the European Union's non-nuclear weapon states. See Goldblat, J., *Arms Control: The New Guide to Negotiations and Agreements* (SAGE: London, 2002), p. 328.

VI. Excessive secrecy

The establishment of warhead disassembly and fissile material disposition transparency is the most challenging part of nuclear disarmament since it directly affects the core of the nuclear complexes and their best-guarded secrets. Currently, there is no nuclear arms control treaty on verification or transparency in warhead disassembly, and there is no tradition for developing such measures. All efforts to introduce greater transparency in this domain have failed, for several reasons.[39]

First, the disclosure of the technical details of warhead design and construction poses proliferation dangers and could conflict with the commitments of the NWS under Article I of the NPT. Information that could accelerate a proliferator's secret nuclear weapon programme, such as the principles of warhead construction or materials manufacture, should not be revealed. However, some states classify information that is not proliferation-relevant or is already in the public domain, even on the Internet.

The second reason has to do with national security. Military planning relies on surprise and therefore on secrecy. In addition, there is often a desire not to reveal the level of technological development, the motive being to hide technological weaknesses or to protect technological superiority. These secrecy policies were part of the nuclear strategy practised during the cold war. Belief in the deterrent effect of nuclear weapons—and the quest for strategic advantage—depended on maintaining uncertainty about intentions and capabilities, even if a degree of transparency was sought through arms control measures where uncertainty threatened to seriously destabilize strategic relations.[40] This tradition also plays a role today.

The third factor that impedes transparency is the status that is traditionally associated with secrecy in the nuclear complexes of the NWS, usually linked to privileges. The disclosure of technical information is perceived as a surrender of status and often as defeat. Many of the best scientists have been attracted to the nuclear weapon programmes of the NWS and proliferator states. As these scientists have been withdrawn from the international community and been unable to publish their research results, they have become dependent on the appreciation of a closed community. However, because nuclear weapon scientists have an interest in being able to communicate with their peers in the wider scientific community, they might not wish to subject themselves to tight restrictions. Secrecy can be perceived as a status symbol not only by nuclear weapon scientists but also by other groups, such as politicians. The belief in a special status conferred by the possession of nuclear weapons often results in an uncritical assignment of status to aspects traditionally associated with nuclear weapons, one of which is secrecy. Conservative politicians who emphasize the

[39] Bunn (note 1), p. 47; and chapter 5 in this volume.

[40] Walker, W., 'Reflections on nuclear transparency and irreversibility: the re-regulation of partially disarmed states', Background paper for the Conference on the Fissile Material Cutoff, Schlangenbad, Germany, 25–27 July 1997.

need for national military strength often exaggerate 'national security' and overestimate the dangers of security leaks to foreign intelligence.[41]

Finally, a fourth reason for the lack of transparency is the lack of democracy. The less democratic a state is, the more it may tend to use secrecy as a convenient cover to avoid criticism. The critics may be citizens of the state or the international community. Secrecy can also serve to cover up mismanagement, corruption or even crime. Furthermore, it may be abused by certain constituencies to set agendas that serve their special interests, preserve autonomy in decision making, maximize their power through knowledge and avoid scrutiny by competitors or the public.[42] The more democratic a state is, the more legal limits are in place against such abuse of secrecy.

The creation of greater transparency therefore requires not only new verification technologies but also domestic policy reforms and international pressure. In the meantime, much work can be undertaken on the technical side.

VII. A universal verification regime for fissile materials?

Over the long term, it will be necessary to focus on fundamental safeguards reforms with the goal of achieving a universal system for both the NWS and the NNWS. However, there are many political and technical hurdles: paving the way for universal acceptance within the NWS and states outside the NPT is a political problem and is likely to be a long process. Implementing safeguards systems, including material accountancy, in these states is a technical issue and will require the investment of time and money.

A global system must be different from the existing system; it must be characterized by a new safeguards culture, based more on technical and political judgement than on the implementation of quantifiable measures. A safeguards reform leading towards that goal will have to address issues of finance, organization, decision making, effectiveness and concern about non-compliance as well as underlying principles such as standards for significant quantities. A global approach could lay the foundation for a nuclear weapon-free world.

[41] The 'Cox Report', which has been criticized for partisan bias and mistakes, examined allegations of Chinese espionage at a US nuclear weapon laboratory. US Congress, House of Representatives, Select Committee on US National Security and Military/Commercial Concerns with the People's Republic of China, *Final Report,* House Report 105-851 (US Government Printing Office: Washington, DC, 25 May 1999), URL <http://www.gpo.gov/congress/house/hr105851>. See also Garwin, R. L. and Panofsky, W. K. H., 'Nuclear secrets: rush to judgment against China', *International Herald Tribune*, 3 Aug. 1999: 'Each of us has a right to make up his or her own mind, but not to make up his or her own facts. Yet that seems to be happening on the nuclear threat from China'.

[42] Walker (note 40).

11. Potential roles for the IAEA in a warhead dismantlement and fissile materials transparency regime

*Thomas E. Shea**

I. Introduction

The elimination of nuclear weapons is likely to be a long process involving limitations on both the weapons and the ability to expand existing arsenals. The nuclear weapon states (NWS) may undertake unilateral arms reductions or engage in bilateral reductions similar to those pursued by Russia and the United States. While further unilateral reductions can be anticipated, arms reductions involving other combinations of the five NWS and the three de facto NWS might become necessary. Successive arms limitations undertaken by one or more of the NWS may encourage the others to follow suit, but this will depend on the level of transparency that is implemented. Transparency measures could be undertaken on a voluntary basis or as part of an agreed framework involving the parties to a negotiated arms control arrangement. Expanding arms control beyond bilateral to multilateral arms reduction arrangements may bring additional benefits in the form of transparency, although perhaps at the expense of additional complications in the negotiation and implementation processes. As new arms reductions are contemplated, transparency measures can accelerate the process of nuclear disarmament by two means. Allowing the public and the media to observe and confirm the steps taken by a state will help to lock in the progress made and put pressure on other NWS to do the same. Transparency measures engender confidence that a NWS is actually pursuing reductions in accordance with its stated intentions and, by observing these steps, other NWS will see that threats have been reduced and be encouraged to reduce their nuclear weapon holdings.

Transparency measures reveal the extent to which actions taken by a state are consistent with its declared intentions. The more complete and timely the measures, the more assurance is provided. If the transparency measures involve an independent organization, then, at a certain point, they become sufficiently formal so as to constitute a form of verification, providing proof that a state's commitments are being honoured.

Assigning transparency activities, including verification, to an independent entity could serve several purposes. First, an independent body would be

* The views expressed in this chapter are those of the author and do not necessarily reflect views of the International Atomic Energy Agency.

unbiased and could therefore be more acceptable than mutual reciprocal verification to all the parties to a multilateral arms reduction agreement. This would become increasingly important as the number of parties to an agreement grew, especially when there was distrust among the NWS. Second, an independent entity would be insulated from the periodic tensions that might arise between the parties to an arms reduction agreement. Third, an independent body could represent the international community, and verification could be seen in the context of meeting obligations under existing and new treaty arrangements, such as those under Article VI of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT). Having an independent entity carry out such transparency activities, including verification, would serve to encourage all the NWS to adopt similar arrangements and collectively strengthen international commitments to nuclear disarmament and non-proliferation.

Transparency in nuclear disarmament is likely to involve activities that are similar or even identical to the International Atomic Energy Agency (IAEA) safeguards measures undertaken for non-proliferation purposes. The non-nuclear weapon states (NNWS) parties to the NPT, which are subject to comprehensive IAEA safeguards agreements, are growing increasingly concerned at the lack of concrete steps by the NWS towards nuclear disarmament. Involving the IAEA in nuclear disarmament would both strengthen the obligations to be fulfilled by the NWS and reduce the gap between the commitments of the five NPT-recognized NWS and those already assumed by the NNWS. Engaging the IAEA to assist with transparency and verification measures seems appropriate and logical as successive steps are taken towards nuclear disarmament. Establishing another body for this purpose could undermine the IAEA safeguards system and would introduce duplicate safeguards responsibilities. The IAEA has the distinct advantage of being an existing, functioning body with a high reputation in the family of international organizations.

IAEA safeguards place controls on the possession, production, storage, use, import and export of nuclear materials, with the goal of preventing the further proliferation of nuclear weapons. All safeguards applications are carried out under agreements between the IAEA and a state and are legally binding on both the state, in terms of its commitments, and the IAEA, in terms of its verification obligations. A system of transparency in nuclear warheads, fissile material and facilities under the responsibility of the IAEA would be most appropriate if it was formally constituted on the basis of legally binding commitments. At this early stage in the process of universal nuclear disarmament, any transparency system involving the IAEA should allow for credible and independent verification of the participating states' commitments to support and encourage progressive nuclear arms reductions.

II. Rising expectations

Controls on fissile materials are certain to be an essential element of international nuclear disarmament. A number of important developments suggest that the IAEA could play a key role in this regard.

1. In 1993 the United Nations General Assembly adopted a resolution which recommended the negotiation of a 'non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices' and requested the IAEA 'to provide assistance for examination of verification arrangements for such a treaty as required'.[1] Little progress has been made since then and, despite recommendations by the UN General Assembly,[2] the Conference on Disarmament has not started negotiations on a treaty.

2. In 1994 the USA for the first time submitted unclassified forms of excess defence fissile materials to IAEA safeguards under its Voluntary Offer Safeguards Agreement as a means of making them unavailable for further military use.[3] All payment of verification costs for such materials was provided by the USA through extra-budgetary contributions. The number of locations and the amounts of excess defence materials submitted by the USA to IAEA safeguards have continued to increase since then.

3. In 1995 the NPT Review and Extension Conference agreed that 'Nuclear fissile material transferred from military use to peaceful nuclear activities should, as soon as practicable, be placed under Agency safeguards in the framework of the voluntary safeguards agreements in place with the nuclear-weapon States. Safeguards should be universally applied once the complete elimination of nuclear weapons has been achieved'.[4]

4. In 1996 Russian President Boris Yeltsin made reference to a role for the IAEA in a statement to the Moscow Summit on Nuclear Safety and Security.

> All nuclear materials resulting from conversion should be used in the civil nuclear area. And, as it is known, this will require no less than 20 to 30 years.
>
> Hence, we stand for the construction of secure storage facilities for nuclear material.
>
> We have completed the design work and are constructing now a similar storage facility at the site of the 'Mayak' industrial complex with US participation.
>
> This storage facility will accommodate about 40 percent of the Russian weapons-grade plutonium. We are planning to place this facility under the IAEA safeguards.

[1] United Nations General Assembly Resolution 48/75, Dec. 1993, URL <http://www.un.org/documents/ga/res/48/a48r075.htm>.

[2] E.g., the General Assembly renewed this call in Resolution 56/24J, which was adopted without a vote on 29 Nov. 2001.

[3] IAEA, The Text of the Agreement of 18 Nov. 1977 Between the United States of America and the Agency for the Application of Safeguards in the United States of America, INFCIRC/288, Dec. 1981, URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/infcirc288.shtml>.

[4] NPT/CONF.1995/32(Part 1): 1995 Review and Extension Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Final Document, Principles and Objectives for Nuclear Non-Proliferation and Disarmament, p. 11, §13m, 1995, URL <http://www.un.org/Depts/ddar/nptconf/2142.htm>.

I believe that this experience should be extended to other countries.[5]

5. In 1996, in response to Russian and US offers, the Trilateral Initiative was launched to investigate the technical, legal and financial issues associated with IAEA verification of weapon-origin and other fissile material released from defence programmes in Russia and the USA (see section VII). In the system under consideration states may submit to IAEA verification classified forms of fissile material, including nuclear weapon components, under new agreements established pursuant to the Trilateral Initiative. The hope is that the legal framework developed under this initiative will serve as a basis for other NWS to accept similar arrangements in the future. In 2000, in the Final Document of the NPT Review Conference, the parties called for the completion and implementation of the Trilateral Initiative.[6]

6. In 2000, Russia and the USA signed the Agreement concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (the Plutonium Management and Disposition Agreement, PMDA).[7] Under the PMDA, both parties are required to begin consultations with the IAEA at an early date and to conclude appropriate agreements with the IAEA to allow it to implement verification activities not later than: (*a*) when disposition plutonium or disposition plutonium mixed with blend stock is placed into the post-processing storage location of a conversion or conversion/blending facility; or (*b*) when disposition plutonium is received at a fuel fabrication or immobilization facility, whichever occurs first. The PMDA makes a further provision that, if agreed in writing by the parties, the exercise of each party's rights with regard to monitoring and inspection may be suspended in whole or in part by the application of equivalent IAEA verification measures. The parties shall, to the extent practicable, avoid duplication of effort in monitoring and inspection activities implemented under the PMDA and appropriate agreements with the IAEA.

7. In 2002 the summit meeting of the Group of Eight (G8) issued a statement in which the members pledged aid for non-proliferation efforts.

[5] Statement by Boris Yeltsin, President of Russia, to the Moscow Summit on Nuclear Safety and Security, 19–20 Apr. 1996, p. 35.

[6] Final Document of the 2000 Review Conference of the parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2000/28, 24 May 2000, Article VI, para. 15.8, available at URL <http://www.iaea.org/worldatom/Press/Events/Npt/npt-2000.shtml>.

[7] See URL <http://www.ransac.org/new-web-site/related/agree/bilat/pudisp-agree.html>. The PMDA, which had not formally entered into force as of Dec. 2002, has been under review by the Bush Administration. The review was concluded in Dec. 2001, and in a White House fact sheet of 27 Dec. 2001 the findings were positive. As noted there, 'The Administration remains committed to the agreement with Russia to dispose of excess plutonium'. US Department of State, 'Fact Sheet: Nonproliferation, threat reduction assistance to Russia', Washington, DC, 27 Dec. 2001, URL <http://usinfo.state.gov/topical/pol/arms/stories/01122701.htm>.

The attacks of September 11 demonstrated that terrorists are prepared to use any means to cause terror and inflict appalling casualties on innocent people. We commit ourselves to prevent terrorists, or those that harbour them, from acquiring or developing nuclear, chemical, radiological and biological weapons; missiles; and related materials, equipment and technology. We call on all countries to join us in adopting the set of non-proliferation principles we have announced today.

In a major initiative to implement those principles, we have also decided today to launch a new G8 Global Partnership against the Spread of Weapons and Materials of Mass Destruction. Under this initiative, we will support specific cooperation projects, initially in Russia, to address non-proliferation, disarmament, counter-terrorism and nuclear safety issues. Among our priority concerns are the destruction of chemical weapons, the dismantlement of decommissioned nuclear submarines, the disposition of fissile materials and the employment of former weapons scientists. We will commit to raise up to $20 billion to support such projects over the next ten years. A range of financing options, including the option of bilateral debt for program exchanges, will be available to countries that contribute to this Global Partnership.[8]

8. In 2000 and 2001, a bill was introduced in the US Senate which would guarantee loans to Russia in return for bringing weapon-usable plutonium additional to the amounts covered under the PMDA and weapon-usable highly enriched uranium (HEU) under IAEA controls.[9]

These steps and declarations collectively suggest that international fissile material controls will shortly begin to be implemented to facilitate the eventual elimination of nuclear arsenals. No state is as yet bound by any specific commitment, but a transparency scheme for nuclear stockpiles and warhead dismantlement may emerge as one of the first steps. It could serve in part as a means to lock in progressive nuclear arms reductions, to inhibit re-armament and to create the climate of trust needed for the acceleration of the elimination of nuclear arms.

The role or roles eventually assigned to the IAEA within the broader scheme of nuclear disarmament measures will require a consensus within the international community. That consensus would evolve over time and the scope of activities would be determined partly on the basis of what the NWS will allow and partly on what the international community is willing to finance. The early assignment of a role for the IAEA in this process would establish a foundation for a more complete and coherent spectrum of future international controls.

[8] 'The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction', Statement by the Group of Eight Leaders, Kananaskis, Canada, 27 June 2002, URL <http://www.state.gov/e/eb/rls/othr/11514.htm>.

[9] Russian Fissile Materials Disposition Loan Guarantee Act of 2001, S.1277, US Senate, 31 July 2001, available on the US Senate Internet site at URL <http://www.senate.gov>.

III. Fissile material controls and nuclear disarmament

All nuclear warheads have fission energy elements that rely on the use of fissile materials,[10] which have only two practical uses—in nuclear weapons or as fuel materials in nuclear reactors. Controls on the production, storage, use and export of fissile materials are accordingly the principal focus of international efforts to stem the proliferation of nuclear weapons and, specifically, of IAEA safeguards. The IAEA safeguards system has matured to a high level of effectiveness and efficiency, and further steps are under way to strengthen its capabilities, particularly in the detection of clandestine military nuclear programmes.[11]

While the circumstances may differ in fundamental ways from the application of IAEA safeguards, a coherent system of fissile material controls could make it impossible for NWS to re-use existing fissile material or to make new material for the production of nuclear weapons. As progress is made towards the elimination of nuclear weapons, such a system could be expanded to include: (*a*) verification of weapon-origin and other fissile material released from military use by states; (*b*) verification of a ban on the production of fissile material for use in nuclear weapons or other nuclear explosive devices, including verification of declared production facilities and the detection of clandestine programmes; and (*c*) estimation of the amounts of fissile material produced by the NWS (the amounts expended, exported and remaining) and a reconciliation of these estimates.[12]

These are the traditional means by which controls on fissile materials can contribute to the elimination of nuclear weapons. They will probably all come into play, especially as deep cuts in the nuclear arsenals of all NWS are contemplated.

Depending on how such a system is designed and implemented, appropriate controls might also provide a potential means to monitor the dismantlement of nuclear warheads and the removal of fissile materials from the production of such warheads, thereby giving the IAEA a more direct role in the verification of nuclear arms reductions.

Completing the physical dismantlement of tens of thousands of warheads and disposing of the tonnes of recovered fissile materials is likely to be a very long process. The amount of fissile material in military use or available for such use is very large and diverse, and it will take decades to make the material unsuit-

[10] For the purposes of this chapter, fissile material means plutonium containing 90% or more of the isotope Pu-239 and uranium containing 90% or more of the isotope U-235. Other materials appear to be suitable for weapon use, in particular Np-237. However, heat, spontaneous fission neutrons and intense gamma-ray emissions would limit the usefulness for weapons of materials such as U-233, Am-241 or Cu-242.

[11] Goldschmidt, P., 'The IAEA safeguards system moves into the 21st century', Supplement to the *IAEA Bulletin*, vol. 41, no. 4 (Dec. 1999), pp. 1–20.

[12] Establishing accurate estimates of past production and use will pose daunting challenges, because the measurement and accounting practices applied were neither complete nor rigorously applied and the people involved are retiring.

able for further use in nuclear weapons. Progress towards nuclear disarmament will require a stable international security environment. A 'Warhead Dismantlement and Fissile Materials Transparency Regime' incorporating IAEA fissile material controls could be an important contribution to such progress.

IV. The statutory basis for the involvement of the IAEA

Any role for the IAEA would require the approval of its policy-making organs, the Board of Governors and the General Conference. The authority for the IAEA to undertake a role could be based on two provisions of the IAEA Statute.[13] Article III.A.5 authorizes the Agency:

> To establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy.

Article III.B provides that:

> In carrying out its functions, the Agency shall:
> 1. Conduct its activities in accordance with the purposes and principles of the United Nations to promote peace and international co-operation, and in conformity with policies of the United Nations furthering the establishment of safeguarded worldwide disarmament and in conformity with any international agreements entered into pursuant to such policies.

V. The legal framework for a role for the IAEA

Following the process established for IAEA safeguards, a role for the IAEA in a future nuclear stockpile and warhead dismantlement transparency regime should be based on essentially identical bilateral legal agreements between the IAEA and states. Each such agreement would require the approval of the IAEA Board of Governors and the state, according to its constitutional practices. There are three basic requirements for such agreements.

1. The agreements should provide that the undertakings by states are irrevocable.
2. The agreements should provide that verification by the IAEA would be obligatory and that the measures employed would permit the IAEA to derive credible and independent findings.
3. The results of the verification should be conveyed to the international community in a manner designed to achieve the intended transparency.

[13] IAEA, Statute of the International Atomic Energy Agency (as amended up to 28 Dec. 1989), URL <http://www.iaea.org/worldatom/Documents/statute.html>.

The IAEA already has safeguards agreements in force with all the NWS.[14] Extending them might, in principle, meet the requirements for the IAEA to play a useful role in a future nuclear stockpile and warhead dismantlement transparency regime. However, for the reasons given in the sections below, such a route does not appear to be appropriate.

VI. The dismantlement process and progressive monitoring alternatives for the IAEA

If the IAEA is to play a role in a transparency regime for fissile materials, warheads and facilities, the regime should represent a balance between providing the most useful service possible and respecting security concerns regarding information on the design of nuclear warheads or the configuration of national arsenals. It may have to reflect pragmatic considerations associated with the high costs and long process that will be required to reconfigure, process and alter the characteristics of fissile material from dismantled nuclear warheads. The IAEA could begin with steps that are meaningful now, with the notion that, as progress is made towards the final elimination of nuclear weapons, its role might be expanded to support the final stages and to facilitate the convergence of all verification systems associated with fissile material.

Figure 11.1 illustrates the steps involved in the dismantlement of nuclear warheads and the disposition of the fissile materials removed from them. The operations at the start of the process involve weapons and weapon components. Extensive security measures are applied to protect the items themselves and the sensitive information pertaining to the warheads. International involvement for the purpose of monitoring that warhead dismantlement is actually taking place could begin at the very start of the process, using the verification procedures described below. Figure 11.1 also shows four alternative points at which monitoring might begin, in order of their relevance to nuclear disarmament.

Option 1: the baseline

In line with the IAEA's core capabilities and the extensive experience gained under its safeguards programme, the foundation for a role for the Agency in a transparency regime should be a system of controls on the fissile materials

[14] IAEA safeguards agreements are incorporated in IAEA Information Circulars, most of which are available on the IAEA Internet site at URL <http://www.iaea.org>. For the nuclear weapon states parties to the NPT, the safeguards agreements are based on INFCIRC/153, June 1972. The specific documents are: France—INFCIRC/290, Dec. 1981; China—INFCIRC/369, Oct. 1989; Russian Federation (Union of Soviet Socialist Republics)—INFCIRC/327, July 1985; United Kingdom—INFCIRC/263, Oct. 1978; and United States—INFCIRC/288, Dec. 1981. Safeguards agreements with India, Israel and Pakistan are based on INFCIRC/66/Rev.2, Sep. 1968. Agreements in force for India are contained in: INFCIRC/154, Sep. 1971; INFCIRC/211; Nov. 1974; INFCIRC/260, July 1978; INFCIRC/360, Jan. 1989; INFCIRC/374, Jan. 1990; and INFCIRC/433, May 1994. The agreement with Israel is contained in INFCIRC/249, Sep. 1977. Agreements with Pakistan are contained in INFCIRC/135, Nov. 1969; INFCIRC/239, June 1976; INFCIRC/248, July 1977; INFCIRC/393, Oct. 1990; and INFCIRC/418, Mar. 1993.

removed from dismantled warheads, after the fissile materials have been processed so that no classified properties remain.

The objective for monitoring the unclassified materials would be to ensure that they are not returned to nuclear weapon use. This measure of assurance, together with a treaty banning the production of fissile material for use in nuclear weapons or other nuclear explosive devices, would limit the ability of states to produce additional nuclear weapons. As successive arms reductions are implemented, the ceilings on the arsenals would be lowered correspondingly if the fissile materials were subject to IAEA verification.

Once the classified properties of the fissile materials have been removed through conversion and blending, the resulting plutonium, HEU and low-enriched uranium (LEU) are essentially identical to those encountered in civil nuclear power programmes. The IAEA and the states involved have extensive experience in safeguarding those materials; hence little remains except to extend the applications to the unclassified forms of material.

Three important issues are associated with such a role—the nature of the verification agreements, the verification timing and intensity, and the point at which verification should terminate.

1. The safeguards agreements in force in the five NWS parties to the NPT, referred to as Voluntary Offer Safeguards Agreements, follow the form of the comprehensive safeguards agreements applied in the NNWS.[15] These agreements were intended to allow the NWS to assist the IAEA in developing safeguards arrangements for similar facilities in the NNWS, providing test beds to establish safeguards approaches, conduct training exercises, and gain experience, particularly in complex facilities. To some extent, the aim was also to provide a means of mitigating the economic burden of IAEA inspections, which would affect competition involving similar facilities in both NWS and NNWS. While in principle it would be possible to modify the Voluntary Offer Safeguards Agreements for the purpose of verifying unclassified materials from dismantled nuclear warheads, these agreements were intended for non-proliferation purposes and are not suitable for a role in nuclear disarmament. They are voluntary in nature, and they allow the state to decide whether it will withdraw facilities and nuclear materials from inspection. It is not clear whether the international community would be willing to finance these inspections under safeguards agreements. Modifications to the Voluntary Offer Safeguards Agreements might address these concerns, but that would still leave open the question of how to engage those states which possess nuclear weapons but are not parties to the NPT. All of this must be seen in relation to the need to apply a uniform standard.

[15] IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), IAEA document INFCIRC/153 (Corrected), June 1972, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>.

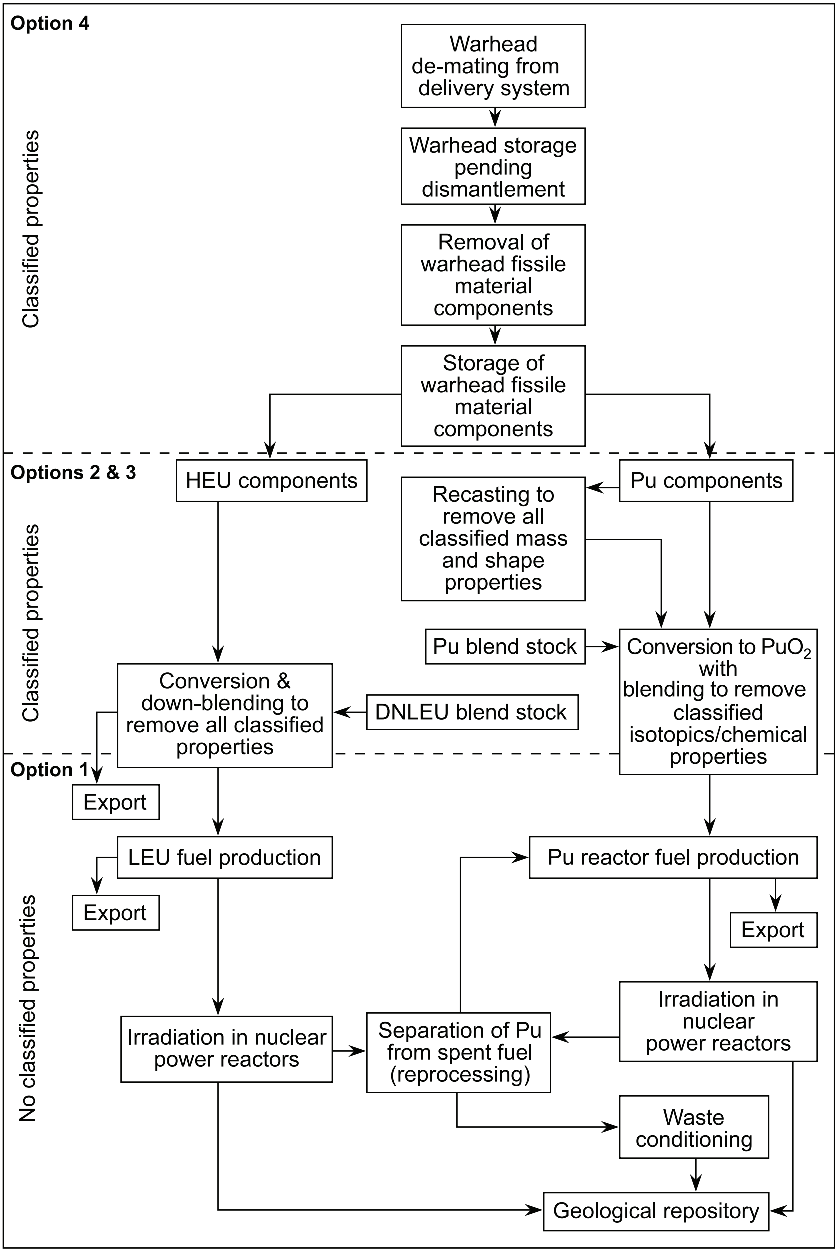

Figure 11.1. Warhead dismantlement and disposition of recovered fissile materials, shown with alternative monitoring starting points

DNLEU = depleted, natural, low-enriched uranium; HEU = highly enriched uranium; LEU = low-enriched uranium; Pu = plutonium; PuO_2 = plutonium dioxide.

Source: IAEA, *IAEA Safeguards Glossary*, 2001 edn, International Nuclear Verification Series no. 3 (IAEA: Vienna, 2002).

2. The technical criteria used for planning and evaluating IAEA safeguards are designed to meet the non-proliferation mission of the IAEA. They provide for the timely detection of the attempt of a state to acquire its first nuclear weapon, before it could reasonably be expected to succeed. If these non-proliferation criteria were to be applied in relation to the transparency of nuclear weapon dismantlement, in some cases it would not be physically possible to meet the requirements. For the foreseeable future, the costs for verification at such intense levels would far exceed any arms control benefit to be derived through the application of such criteria.

As progress towards the elimination of nuclear weapons is made, it will become necessary for all verification arrangements and requirements to converge so that all states are subject to a single, non-discriminatory framework.

3. In the Final Document issued at the NPT Review Conference in May 2000, the NPT parties agreed that the principle of irreversibility should apply to nuclear disarmament as well as to nuclear and other related arms control and reduction measures.[16] In comprehensive IAEA safeguards agreements, there is a provision that 'safeguards shall terminate on nuclear material subject to safeguards upon determination by the Agency that it has been consumed, or has been diluted in such a way that it is no longer usable for any nuclear activity relevant from the point of view of safeguards, or has become practicably irrecoverable'.[17] In an absolute sense, the safeguards interpretation could also define the end point for verification of fissile material in relation to disarmament. Should this same definition apply? Should it apply at the outset or should the verification requirements converge as the elimination of nuclear weapons approaches?

There is little benefit for arms control in spending significant resources on fissile materials following plutonium irradiation or down-blending of HEU. This view is reflected in the bilateral PMDA, the provisions of which will apply until pure plutonium is irradiated to specified levels or impure plutonium is immobilized for geological storage. Concentrating on the upstream activities associated with disposition would focus the effort on the most significant material forms in relation to nuclear disarmament and would reduce the costs of verification accordingly. For HEU, the requirements to follow down-blended uranium could be correspondingly expensive and not bring a great deal to the practical matter of verifying disarmament, until the elimination of existing nuclear arsenals approaches and convergence becomes essential.

However, applying the safeguards definition of the principle of irreversibility from the outset would have the advantage of establishing the verification framework in a manner that would anticipate the convergence foreseen as nuclear arms are eventually eliminated. It would also serve to erode the special status of the NWS under the NPT and could strengthen the commitments of NNWS.

[16] Final Document (note 6), Article VI, para. 15.5.
[17] INFCIRC/153 (note 14), para. 11.

Adopting these provisions at the outset could increase the willingness of the international community to pay for the required verification activities and could facilitate future NPT review conference deliberations.

A pragmatic means to proceed could involve establishing the principles of the agreements as early as possible. The technical criteria employed for planning and evaluation purposes would be modified over time. The inspection burden on the downstream materials would not be the same as that in NNWS until progress towards the elimination of nuclear weapons had advanced and a treaty banning the production of fissile material had entered into force.

Option 2: introducing classified forms of fissile material into the monitoring system

Moving the starting point of the verification of the dismantlement process forward would allow the monitoring system to be applied at a much earlier stage and forge a stronger linkage between the source of the materials and their ultimate disposition. It would also cost more and be more invasive than Option 1. Including classified forms of fissile material raises three security-related issues.

1. Appropriate measures must be taken to prevent the disclosure of classified information related to the design or manufacturing of nuclear warheads. All states possessing nuclear warheads would ensure that any verification arrangements are carefully examined to prevent intentional, inadvertent or unauthorized disclosures of such classified information. NWS parties to the NPT are obligated under Article I to take such precautions. Each step will involve considerations by the classification and security officials of the NWS. The requirements they apply and the decisions and related conditions are unlikely to be the same in each state.
2. In the course of carrying out their respective monitoring activities, IAEA inspectors will routinely receive information normally considered to be of a sensitive nature (e.g., on features of facility design and operational practices at facilities where weapon-related activities are carried out, on physical inventories and on aspects of the physical protection measures that are applied). Managing these activities, while allowing the IAEA inspectors to carry out their inspections in such a manner as to be able to derive credible, independent conclusions, will require both close attention to procedures and equipment and close supervision of inspectors within sensitive facilities.
3. The IAEA would have to assure the states that its inspectors would not be able to acquire unauthorized information. Nothing would diminish support for international verification of sensitive activities more quickly than an attempt by an IAEA staff member to misuse the opportunities and access provided in the course of his or her duties.

The provisions of the legally binding verification agreements would have to reflect both the rights and the restrictions of the state and the IAEA in relation to these security considerations.

Again, modifying the Voluntary Offer Safeguards Agreements to facilitate special conditions could undermine the implementation of safeguards in NNWS. The modifications would have to allow the states to withhold classified information from their declarations and would have to limit the inspection activities and equipment to prevent access to classified information. The problem is that such modifications could establish a further distinction between the NWS parties to the NPT and NNWS, and could serve to undermine the collective integrity of the IAEA non-proliferation safeguards system. Taking into account these considerations and the fact that not all NWS are parties to the NPT, a new verification agreement becomes increasingly attractive.

The new verification agreements being developed under the 1996 IAEA–Russian–US Trilateral Initiative envisage that weapon-origin and other fissile materials released from defence requirements in Russia and the USA, in classified or unclassified forms, could be submitted to IAEA verification. It would be up to each state to decide when, where and in what form its material would be submitted but, once submitted, the commitment would be irrevocable. Verification under the new agreements would ensure that the materials remain accounted for and are not used thereafter for any military purpose. The verification methods under development are believed to be suitable for any situation in which classified forms of fissile material are presented.

Under the Trilateral Initiative, it is foreseen that the two participating states may submit classified forms of fissile material to IAEA verification, including nuclear warhead components. When either state determines that its fissile material retains nuclear weapon information, the declaration accompanying a submission to IAEA verification would state whether the material mass (and virtually all other physical parameters) or the isotopic or chemical composition is classified. Corresponding to classified forms of plutonium and HEU, unclassified reference values are specified for the minimum ratio of plutonium-240 to plutonium-239 and the minimum percentage of uranium-235 enrichment. Minimum mass values are also specified, although these values may be facility-specific.

Three attributes are to be verified for classified forms of plutonium under the Trilateral Initiative: whether plutonium is present within the container; whether the ratio of plutonium-240 to plutonium-239 is 0.1 or less; and whether the amount of plutonium present in a container exceeds the specified minimum mass value. If a container passes these tests, it will be accepted for verification. If not, since the classification restrictions prevent further investigations into why the tests might not have been passed, the container will be rejected and removed from the facility.

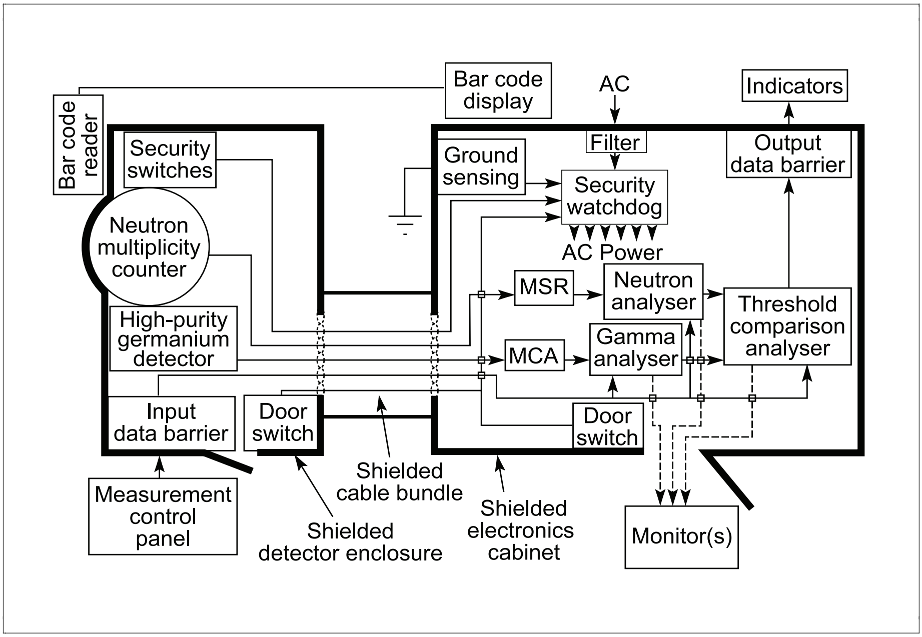

Figure 11.2. Attribute verification system for classified forms of plutonium, including 'information barriers'

AC = alternating current; MCA = Multi-Channel Analyser; MSR = Multiplicity Shift Register.

Sources: The system shown in the figure and the specific hardware solutions have been developed under the Trilateral Initiative. It is referred to as an 'enabling technology'. Variations of the same technology are being introduced in other bilateral fissile material agreements between Russia and the USA. See, e.g., Whiteson, R. *et al.* 'A prototype inspection system with information barrier for the Trilateral Initiative, *Proceedings of the 40th Annual Meeting of the Institute for Nuclear Materials Management (1999)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

There have been attempts to determine whether there are any quantitative measurements that could be made without providing information that would allow classified properties to be deduced. No such measurements have been found. The approach that was decided upon, and is now being developed, employs robust non-destructive assay measurement methods typical of those used in IAEA safeguards, but with the instruments operating within an 'information barrier' security framework. Figure 11.2 illustrates this concept.

A significant amount of work remains in order to gain certification by the Russian and the US security authorities and to ensure that the authentication provisions applied will allow the IAEA to derive credible and independent conclusions.

For plutonium, the attribute verification measurement system will comprise a high-resolution gamma-ray spectrometer[18] integrated with a neutron multiplicity assay system.[19]

The detector systems are essentially identical to those used for IAEA safeguards purposes, but access to the signals is prohibited when classified forms of fissile material are present. The general technical requirements and associated functional specifications for such systems have been agreed. A prototype system was developed and demonstrated, and full-scale systems are currently being produced in Russia and the USA under the direction of a Trilateral Initiative experts group.

Once classified forms of fissile material are submitted for verification, since the commitment is irrevocable, they will eventually be removed from storage for disposition as shown in figure 11.1. From the perspective of protecting the classified information, the conversion operation is the most sensitive. Under the Trilateral Initiative, special provisions are made in the model agreement for such conversion operations. The verification arrangements would allow the IAEA to be confident that all inputs satisfy the attribute tests identified and that the declared conversion operations actually occur. Furthermore, it would be assured that the converted forms, no longer characterized by any classification restrictions, are measured quantitatively and are subsequently shipped to a fuel fabrication facility or exported. Verification would continue in both cases, either under the new agreement (assuming the material remains within the state or is shipped to another state possessing nuclear weapons) or under a comprehensive IAEA safeguards agreement if the material is exported to a NNWS.

The verification arrangements for such conversion facilities would entail a perimeter control system around each facility, with attribute verification of inputs and quantitative verification of outputs. Moreover, periodic managed-access design verification visits within the facility would ensure that no possibilities had been created for classified materials to be removed without verification.

Under the Trilateral Initiative, technical criteria are being established to serve as the basis for determining the requirements for various forms of material and operations. Requirements for the timing of successive inspections and the intensity of verification are being designed to reflect the disarmament nature of the undertaking, and the fact that there are no follow-up possibilities to resolve measurement anomalies for classified forms. Unattended monitoring systems

[18] High-resolution gamma-ray spectrometers incorporate high-purity germanium semiconductor detectors. Individual gamma rays strike the detector and the response is proportional to the energy of the incident gamma ray. A spectrum accumulated over time shows a distinctive form which is dependent upon the isotopic composition of the plutonium present.

[19] The even-numbered isotopes of plutonium spontaneously fission according to defined half-life values. A neutron multiplicity assay system measures the rate at which two and three neutrons are detected within a very limited time, corresponding to the emission characteristics of spontaneous fission. Measuring both two- and threefold coincidence allows for corrections to be made for neutrons emitted through induced fission reactions within a sample and, for non-fission events, reactions on low atomic number nuclides.

are featured in most applications as a means of providing measurements on all items passing a control point, while limiting inspector presence and minimizing inspection costs.

Option 3: providing added assurance that the fissile material actually originates from dismantled nuclear weapons

Under Option 2, the IAEA would not be able to establish that the materials submitted for verification actually came from dismantled nuclear warheads or that items declared to be nuclear warhead components were in fact warhead components. It would be possible through additional measurements on items submitted for verification to gain further confidence concerning such declarations. Two avenues might be explored.

First, additional attributes characteristic of nuclear warhead components might be verified by extending the analysis of data acquired with the help of high-resolution gamma-ray spectrometry and neutron multiplicity measurements. Three additional attributes have been considered for plutonium components: (*a*) the presence of americium, indicating that the plutonium has not been processed for some years and thus is not newly created; (*b*) the absence of oxygen, which indicates that the plutonium is in metallic form; and (*c*) the presence of other materials associated with plutonium weapon components, including low atomic number elements, such as beryllium.

The second possibility involves the creation of a radiation template for each model of a nuclear warhead component. Since nuclear warheads are manufactured to meet very high tolerance standards, a combined fingerprint made using spatially sensitive measurements should be sufficiently unique for items to be discriminated. Having such a capability would allow the verification to be extrapolated to the characteristics of the items submitted, to determine the number of components of a given model. Whether or not such information is too sensitive for the NWS is an issue that would require careful consideration and have to be balanced against the anticipated stimulus to further arms reductions.

All of these possibilities would require considerable development and testing. Each would raise additional issues concerning the protection of classified information, and each would entail additional costs and the possibility of false measurement results.

Radiation templates would require a reliable means of calibration that would not in itself reveal classified information. If successful, such templates could offer additional information regarding the character of the dismantled warheads, and that information could allow inferences to be drawn regarding the remaining capabilities of a state. This type of information might become increasingly important as deep cuts in existing arsenals become a reality.

Option 4: monitoring dismantlement

A fourth option presupposes that IAEA inspectors are allowed to witness the de-mating of warheads from missiles and that they could carry out attribute verification tests of each warhead and apply appropriate IAEA seals to the warhead. They would be able to record identifying information, including the type of missile, its identification number, and the types of warheads and their serial numbers. IAEA inspectors would be able to verify both the storage of such warheads pending dismantlement and the dismantling operations by means of a perimeter control arrangement such as that described in Option 2.

Moving the starting point of the monitoring system to the starting point for dismantlement would allow the IAEA to establish the source of all components and to ensure that the removed fissile materials were kept under verification throughout the disposition activities. The IAEA verification would be directly coupled to the arms reduction process through this means and the information provided would confirm the state's declarations regarding which weapons were in fact destroyed.

As in Options 2 and 3, the additional monitoring activities would raise implementation costs and cause additional security concerns.

VII. The Trilateral Initiative

Option 2 provides practical means to begin bringing surplus military fissile materials under international control. It is a step which Russia and the USA support and which allows progress to be made without ruling out more extensive measures at a later date. It does, however, raise concerns regarding the protection of classified information, which would be much more complex under Options 3 or 4. Option 2 provides a framework for ensuring that fissile material submitted to IAEA verification cannot be used except in peaceful applications. Moreover, as long as any classified properties are removed through conversion and blending, it offers a means to determine quantitatively just how much fissile material has been removed from defence programmes. However, this is not all that is needed; a treaty banning fissile material for use in nuclear weapons or other nuclear explosive devices and the other steps identified in section II must also be implemented.

The Trilateral Initiative places the IAEA in the middle of what would otherwise be a bilateral arrangement between Russia and the USA. Both states have indicated their continued support and commitment to the Trilateral Initiative, but neither has yet made any formal obligation. Even binding themselves to restrictions on the future use of the excess fissile material is a difficult decision that has to be weighed against the benefits of additional transparency in general and of showing distinct progress in relation to Article VI of the NPT in particular. Going beyond the commitments under Article VI, to submitting fissile material with classified characteristics to controls, brings the additional benefit of early and significant transparency but also brings the concomitant concerns regarding the protection of weapon secrets.

Progress towards the completion and implementation of the Trilateral Initiative requires the continued interest and support of the parties. Since its inception, the administrations of both states have changed and the importance of the Trilateral Initiative has varied accordingly. Before the PMDA was concluded, the conditions of that bilateral agreement served as a means for deferring considerations related to downstream activities. Now, it is essential to come to a common understanding in a single verification framework. Another factor affecting the successful outcome of the Trilateral Initiative is the issue of symmetry: Russia has opted to convert its pits into solid plutonium balls and, while the mass of plutonium and its shape will no longer be classified, other properties will remain classified. Meanwhile, the USA will store pits, converting them only as feed for a mixed oxide (MOX) fuel fabrication facility when the facility becomes operational. Whether the two states can accept each other's terms of participation or not is an issue that has been important and may remain so.

Starting with two states is complicated in itself. Russia and the USA have different inventories, capabilities and intentions. Obtaining the extensive financial support needed to carry out the plutonium disposition activities called for in the PMDA may determine whether it is possible to obtain commitments to a full-scope undertaking. In the absence of sufficient funding for plutonium disposition, agreements limited to storage may have to suffice for now.

Even if all the issues up to this point can be resolved, acceptance by the IAEA Board of Governors and the General Conference is not assured. Some may question the statutory right of the IAEA to engage in verification related to disarmament. Others will question why they should contribute finances to solve a problem that the NWS have created. A parallel consideration will certainly be argued: just as all states benefit from non-proliferation and agree to pay the costs of IAEA safeguards, all states would also benefit from progress towards nuclear disarmament and should therefore support disarmament verification through arrangements similar to those applied for safeguards.

Adding more states will become desirable—and later important and then essential—if the Trilateral Initiative is to lead to a general arms control measure. The other three NPT-recognized NWS may or may not be interested in joining such a regime. They may be disinclined at present to move towards anything approaching a limitation on their respective stocks. They may also be reluctant because this is a 'trilateral' initiative, from which they were excluded in the formative period.

Going beyond the NPT-recognized NWS to the three de facto NWS raises the fundamental question of a framework in which the states in both groups could meet for discussion. A transparency system for fissile materials, warheads and facilities may provide a means to bring about such a framework. Without one, it is unrealistic to think that the Trilateral Initiative model could be extended to all the NWS. Progress towards the universality of a control system for fissile material made surplus through nuclear arms reductions will require leadership, capital and motivating arguments. All the NWS will have to support such a step, and the rest of the international community will need to see, in the creation of any nuclear disarmament transparency regime, the possibility of a world in which international security will be enhanced.

VIII. Further considerations

A role for the IAEA in the context of a dismantlement transparency regime would require a new legal framework and a reliable funding source to cover the costs of staff and equipment. A new legal framework is needed because the existing Voluntary Offer Safeguards Agreements in the five NPT-recognized NWS are voluntary and were not designed for disarmament. For classified forms of fissile material, they would require information that could not be provided by the state and Agency inspection activities that could not be allowed because they would divulge sensitive nuclear weapon design information. In the de facto NWS, the IAEA safeguards agreements in force serve limited objectives and are not at all appropriate for a disarmament verification system. A new legal framework would provide a common basis for verifying excess fissile material in all the states possessing nuclear weapons..

Costs associated with the Agency's role in the context of dismantlement transparency should be borne by all IAEA member states, according to an appropriate formula. The willingness of states to pay for such an activity will depend on the value that they see in bringing about progress towards the elimination of nuclear weapons. There are various mechanisms available for providing funds according to a mandatory assessment scheme and it will be up to the IAEA Board of Governors to adopt what it believes to be the most appropriate arrangement.

In this role for the IAEA, consideration will have to be given to the relationship between the activities under a transparency regime for fissile material, warheads and facilities and the existing operations of the IAEA, especially those of the Department of Safeguards. There will be a need to ensure that the staff and equipment required for this role do not in any way undermine the effectiveness of the IAEA safeguards programme.

IAEA safeguards are applied in all NWS, albeit on a limited-scope basis. It will be necessary to ensure that there are no cases in which both safeguards and the new arrangements are applied to the same material. There should also be no cases in which safeguards and the new arrangements are applied to different materials within the same facility.

When a treaty banning the production of fissile material enters into force, or even in the period when the technical specifications of its verification system are being defined, it will be necessary to harmonize the requirements for similar materials with verification arrangements for the facilities that are affected.

Addressing harmonization with safeguards and implementation of the treaty will require careful consideration since the links are fairly extensive.[20]

IX. Conclusions

Although substantial progress has been made towards reducing the armaments maintained by the two principal adversaries of the 20th century, the decisions regarding what and where to cut remain exclusively within the Russian–US bilateral arena. There are no treaties in place involving international verification specifically in relation to nuclear disarmament and no framework exists which could provide a means for involving any other NWS. Whichever verification starting point is chosen, future developments will ultimately determine the role of the IAEA.

At present, many questions remain to be resolved. What confidence-building measures would be useful and, in a general sense, how might the IAEA contribute to the broader agenda? How should an international control regime begin, what should be controlled and how 'strict and effective' do the controls need to be—especially at the beginning? How can future growth be encouraged and incorporated? What type of legal framework would best meet the objectives of such an international control regime? Should the IAEA be assigned such responsibilities or should a new organization be created for this purpose? How should activities assigned to the IAEA be financed? How might such a role affect the IAEA non-proliferation safeguards programme? What impact would a fissile material production cut-off treaty have on such a regime?

The starting point for IAEA verification in relation to a nuclear stockpile and warhead dismantlement will seek to balance interests that may be in conflict.

1. The international community may wish to obtain as much transparency as possible, as early as possible.
2. Unless carefully controlled, international verification might undermine the ability of a NWS to protect its security. Thus, each state will have to examine all the details of verification before allowing inspectors into sensitive facilities or even to sites where sensitive activities are carried out.
3. Neither states nor any verification body would wish to see international verification further the weapon ambitions of other states or sub-national groups. Hence, information that could be made available for verification and the verification measures themselves may be limited by the need to prevent the disclosure of nuclear weapon design or manufacturing secrets.

The Trilateral Initiative represents a significant, concrete step forward. Although it is being pursued on a voluntary basis, all three participants have an interest in seeing it lead to a successful outcome. Assuming that the responsibil-

[20] Shea, T., 'Reconciling IAEA safeguards requirements in a treaty banning the production of fissile material for use in nuclear weapons or other nuclear explosive devices', *Disarmament Forum* (no. 2), 1999, pp. 57–71, URL <http://www.unidir.org/pdf/articles/pdf-art245.pdf>.

ities identified under the PMDA merge with the verification of plutonium storage, it will probably take 25 years or more to complete the disposition of the 68 tonnes of plutonium covered in the PMDA. During that time, much could happen—a treaty banning fissile material production, or perhaps even an arms reduction agreement that engages all NWS, could be concluded. Implementation of the Trilateral Initiative would be a good first step, and the other NWS could sign similar verification agreements on the disposal of their surplus fissile material stocks as they engage in the process of nuclear disarmament.

The case for bringing the verification starting point forward in the dismantlement process will depend on resolution of the technical issues in a way that dispels concerns about the protection of confidential information. Beyond that, there is the larger issue of the extent to which the monitoring of warhead dismantlement will itself contribute to removing some of the uncertainties that will inevitably arise as the number of weapons declines as well as the extent to which enhanced transparency will stimulate progressive reductions, thereby accelerating the ultimate elimination of nuclear weapons. All things considered, the Trilateral Initiative is an important, pragmatic starting point.

Part III

Summary and conclusions

12. Conclusions

Nicholas Zarimpas

The chapters in this volume demonstrate that greater transparency in the management of nuclear warheads and materials would genuinely contribute to the strengthening of international security, the reduction of nuclear-related threats and the enhancement of predictability in inter-state relations. Transparency would gradually introduce accountability in the nuclear weapon states (NWS) and thus contribute eventually to reducing the asymmetries between them and the non-nuclear weapon states (NNWS). It would facilitate arms control and oversight of the irreversibility of reductions. Ultimately, transparency would help to pave the way for nuclear disarmament.

Today, societies are becoming increasingly open and interdependent, and, as in other areas, they demand greater transparency in the domain of nuclear weapons. A wealth of tried and tested technical means and technologies are available to serve the purpose of transparency and to ensure compliance with nuclear arms control agreements, and more methods are under development. Paradoxically, despite the ever-increasing sophistication of technical capabilities, progress towards enhanced transparency has been limited and the political commitments to this goal have largely been unfulfilled.

This volume maps out in detail the advances that have been made and identifies and discusses the broad reasons for promoting or impeding transparency. However, many important questions remain unanswered. Will the NWS accept more openness and accountability in the future, or will the trends of the 1990s towards greater transparency be halted or even reversed? In particular, will Russia and the United States eventually agree to address the issue of non-deployed warheads, including warheads for their tactical nuclear weapons? To this end, will they adopt some of the proposed transparency technologies, strengthen cooperation and agree to assign a more prominent role to the International Atomic Energy Agency (IAEA)? Finally, what type of action can China, France, the United Kingdom and the three de facto NWS—India, Israel and Pakistan—be expected to take?

I. Progress

Because of the importance attached by the NWS to nuclear weapons, they do not easily accept any disclosure of information that may increase the vulnerability of the weapons or impede their readiness for use. However, there has been an evolution in transparency over the years as the concept, together with the progress made in arms control, has slowly become a central feature of nuclear diplomacy and found its way into the policies of the NWS. In a largely uncoordinated and informal manner, the NWS have released information about their nuclear histories, including information on nuclear tests, doctrines and strategies, and weapon and fissile material inventories, and about the status of their production facilities. Most importantly, they have shared information about their disarmament efforts. Although the information which has been made public varies widely, in both extent and quality, between countries, the UK and the USA have gone a step further in a difficult area in which progress has been particularly constrained. They have provided precise, albeit limited, official data on their nuclear assets.[1] In contrast, in the de facto NWS secrecy remains the norm even today.

Important events took place during the first half of the 1990s, when transparency in nuclear reductions was elevated to one of the primary means for building a stable post-cold war international order. Together with the implementation of their formal nuclear arms control agreements, Russia and the USA pursued a complex and ambitious agenda, closely cooperating on a number of new fronts. They enhanced warhead and fissile material security, improved material accounting and jointly evaluated innovative approaches to providing assurances about the disposition of excess nuclear warheads and materials. Between 1994 and 1997 Russian President Boris Yeltsin and US President Bill Clinton issued a number of summit declarations and official statements calling for, to cite one example, 'measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads'.[2] The two presidents agreed to develop processes for the regular exchange of classified data on their countries' nuclear stockpiles, reciprocal inspections of material originating from dismantled warheads and the establishment of a dialogue at the expert level to propose specific transparency measures. The formal implementation of such provisions, leading to what might be called a 'nuclear glasnost', was never successfully accomplished, mainly because of the sustained resistance to openness in Russia and to a lesser degree in the USA and their rapidly deteriorating relations during the second half of the 1990s.

Nevertheless, the momentum was not entirely lost, because the unprecedented technical cooperation between the two countries led to the pursuit of a number of fragmented initiatives. These mainly involved the monitoring of the disposition and storage of excess fissile material and the closure of related production facilities. Moreover, a framework was conceived for assigning an initial verifi-

[1] It should be underlined that, more than half a century after nuclear weapons were invented, there are significant uncertainties about their numbers and operational status and about the stockpiles of military fissile materials. Fortunately, academic research based on open sources has addressed this gap in knowledge. Although the precision of the findings has often been remarkable, such research cannot replace voluntary, orderly state transparency. See Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997).

[2] Joint Statement on Parameters on Future Reductions in Nuclear Forces, The White House, Office of the Press Secretary, Washington, DC, 21 Mar. 1997, available on the Carnegie Endowment for International Peace Internet site at URL <http://www.ceip.org/files/projects/npp/resources/summits6.htm#parameters>.

cation role to the IAEA. At the same time, warheads and warhead production complexes were conspicuously absent from the agenda.

Although such exchanges were not always smooth or free of problems, it should be acknowledged that, overall, they were extraordinarily useful for a number of reasons. Government institutions and nuclear experts jointly explored novel areas of arms control and helped to gradually build trust, a necessary precondition for access to sensitive nuclear weapon facilities. Problem areas were identified and solutions actively sought, and it became evident that future, more intense cooperation would be feasible. It also became clear that it might be possible to expand select programmes to involve other NWS.

II. Technical considerations

In order to establish the basis for deep cuts in nuclear arsenals, uncertainties surrounding warhead and fissile material inventories must be reduced to a minimum. In addition, if the size of the stockpiles remains unknown, progress in arms control and disarmament cannot be measured in any meaningful manner. Indeed, the early exchange of stockpile information constitutes a logical next step in arms control.[3] The declassification of certain characteristics of the British and US stockpiles set an important precedent.

After confidence is gained from exchanging aggregate data, more detailed accounts could be provided by the NWS in a phased manner. These might include inventories by type, as well as itemized lists of warheads and fissile materials, accompanied by information on their locations. When current stockpiles are substantially reduced or when an agreement is reached to impose quantitative limits on them, it will become imperative to be able to verify such detailed declarations in order to provide assurances about their accuracy and completeness.

The direct imposition of controls on warheads and the provision of assurances about their destruction would be an ambitious and challenging technical task. As units of arms control accountancy, nuclear warheads are too small to be monitored by traditional national technical means. Thus, transparency in warhead dismantlement would necessarily require unprecedented intrusiveness into what have been some of the most sensitive segments of national defence establishments.

The US–Russian Laboratory-to-Laboratory Warhead Dismantlement Transparency Programme, initiated in 1995, and US efforts to develop technology for transparency measures made major advances in many areas, including: (*a*) radiation measurement, (*b*) information-barrier systems, involving both technology and procedural elements, (*c*) remote monitoring, (*d*) disposition of non-nuclear components and (*e*) chain-of-custody arrangements, including tags

[3] Müller, H., *The Nuclear Weapons Register: A Good Idea Whose Time Has Come*, PRIF Reports no. 51 (Peace Research Institute Frankfurt (PRIF): Frankfurt, 1998), available at URL <http://www.hsfk.de/downloads/prifrep51.pdf>.

and seals. Nonetheless, the technology base for warhead dismantlement transparency is far from complete.

The implementation of warhead transparency would have a profound impact on warhead production and maintenance complexes. These facilities were not designed to receive foreign inspectors or accommodate any other transparency measures, such as monitoring. Consequently, warhead stewardship and re-manufacturing operations, which are typically carried out in the same buildings in which dismantlement is performed or in adjoining ones, could be seriously disrupted. In addition, the demands on technical, support and security personnel, services and equipment are likely to be significant. The physical segregation of warhead dismantlement processes and the use of dedicated facilities or plants that have been closed are methods that could be used to implement transparency and at the same time comply with the rigorous operational and security standards in force in warhead complexes.

Problems of an even more serious nature would also need to be resolved. Asymmetries in the number, capacity, structure, function and technical organization of both warhead production facilities and dismantlement facilities in the NWS must be clearly identified and well understood before inspection and monitoring arrangements can be formally negotiated. Notable in this regard is the work in the United States of the joint Department of Defense–Department of Energy Integrated Technology Steering Committee, which was established in 1999 to examine monitoring technologies and issues of cost, impact on the facilities investigated and vulnerability of facilities.[4]

The most likely first steps towards establishing transparency in warhead complexes include exchanges of unclassified dismantlement facility diagrams showing layouts and warhead flows. These could be followed by familiarization tours at the facilities, funding of facility-specific studies, cooperative research on chain-of-custody arrangements for warheads, studies of measures to verify the closure or conversion of warhead production plants and the establishment of technology development centres.

Controls on warheads alone, with no effect on their entire life cycle and production complexes, would not be sufficient for carrying out deep and irreversible reductions in nuclear arsenals. Detecting the undeclared manufacture of new warheads would not be an easy task, but rapidly advancing technologies, such as high-resolution satellite imagery, remote sensing and environmental monitoring, would be valuable instruments. Societal verification could complement them.

In order to ensure the irreversibility of nuclear weapon reductions, transparency and verification measures should be fully extended to material no longer required for military purposes, covering both its intermediate storage in various forms and its final disposition. Material that is not in warhead components or other classified forms—that is, material irradiated as fuel in reactors,

[4] Concher, T. R. and Bieniawski, A. J., 'Transparency questions looking for technology answers', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

undergoing processing in bulk-handling facilities or in storage—can, in general, be monitored with confidence with the available technologies used widely by the IAEA, the European Atomic Energy Community (Euratom), and national systems of accounting and control. The Trilateral Initiative, launched in 1996 by the IAEA, Russia and the USA for the voluntary international verification of both classified and unclassified forms of excess fissile material, is an important step in this regard. If it is concluded, an unbiased, independent body would, for the first time, be able to assure the public that the NWS were honouring their commitments. Together with implementation of the Trilateral Initiative, solid progress could be made by harmonizing the technical specifications of its monitoring provisions with those of other bilateral arrangements, such as the Plutonium Management and Disposition Agreement (PMDA),[5] and arrangements for the Mayak storage facility in Russia.

The IAEA safeguards techniques that have long been applied worldwide could also be utilized to verify the closure of production reactors and military fuel cycle facilities. A concrete step towards this end would be the successful negotiation of a fissile material production cut-off treaty, the prospects for which, after several years of fruitless discussion, are currently remote.

III. Obstacles

Warhead and fissile material transparency raises many political questions, economic considerations and technical problems. Indeed, enhancing and institutionalizing transparency may seem to be an impossible undertaking. The debates on transparency often focus on the protection of national sovereignty and highly sensitive data, the need to prevent nuclear proliferation and the technical obstacles connected with the immensity of the task.

The main obstacles, apart from the need to maintain mutual trust and good relations between the NWS and between the NWS and the major NNWS, are summarized below.

Different objectives

The NWS will accept greater transparency only if they see it as clearly reinforcing their national security. Pursuing the goals of arms control and disarmament is important but not as critical. Simply put, pursuing transparency measures cannot be disconnected from strategic and political realities. Transparency measures must not undermine national interests; indeed, they must be guided by national interests. For example, the USA has long called for enhanced transparency in Russia's tactical nuclear weapon force and in its inadequately protected stockpiles of fissile materials. Russia, for its part, has called for the

[5] The US–Russian Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, 1 Sep. 2000, available at URL <http://www.ransac.org/new-web-site/related/agree/bilat/pudisp-agree.html>. The PMDA had not entered into force as of Dec. 2002.

extension of controls to the reserve stockpile of US strategic warheads. Moreover, openness and accountability, clearly influenced by culture and tradition as well as by political and legal systems, are perceived very differently by different countries. Even though the British and US declassification of certain characteristics of their stockpiles has not undermined their security in any way, it has not been emulated by the other NWS.

Lack of technological readiness and protection of classified information

It is clear that, apart from the political difficulties, various technical obstacles have also impeded the extension of the bilateral security and nuclear arms control agenda to include the elimination of nuclear warheads.[6] One of the key challenges has been to develop cooperative arrangements for effective transparency in warhead dismantlement that would not inadvertently reveal design strengths and vulnerabilities or disrupt routine nuclear weapon maintenance and stewardship activities. The asymmetries that exist in warhead production and dismantlement capabilities and in the availability of secure storage for nuclear materials and warheads have been identified as posing some of the most difficult challenges to introducing transparency. Moreover, the sheer size of military fissile material stockpiles presents additional barriers. There must be accountancy, with a reasonable degree of confidence, for the inevitable uncertainties and the lack of historical data will have to be addressed. Finally, even if monitoring and inspection activities were performed by an international inspectorate there would still be legitimate concerns about the leakage of classified data, in particular if inspectors from the NNWS were involved.

Reciprocity and multilateral engagement

Past efforts have quickly stalled when there was not enough progress, support or interest from the other side. It is unlikely that any of the NWS will forcefully pursue measures if the other NWS do not readily reciprocate. By and large, only Russia and the USA have maintained a dialogue and technical exchanges on transparency. Although these two states bear the primary responsibility for reciprocal transparency because of the size of their nuclear assets and should naturally lead the way, no framework has been devised for engaging, politically or technologically, the other three NWS. The lack of discernible progress on a

[6] See the contributions in Part II of this volume. See also British Atomic Weapons Establishment, *Confidence, Security and Verification: The Challenge of Global Nuclear Weapons Arms Control*, AWE/TR/2000/001 (Aldermaston: Reading, Apr. 2000), available at URL <http://www.awe.co.uk/main_site/scientific_and_technical/publications/pdf_reports/awe_study_report.pdf>; Bukharin, O. and Luongo, K., *US–Russian Warhead Dismantlement Transparency: The Status, Problems and Proposals*, PU/CEES Report no. 314 (Princeton University, Center for Energy and Environmental Studies: Princeton, N.J., Apr. 1999), available at URL <http://www.ransac.org/new-web-site/pub/reports/transparency.html>; Norris, R. S. *et al*., 'Techniques and procedures for verifying nuclear weapons elimination', *Background Papers*, Canberra Commission on the Elimination of Nuclear Weapons, Aug. 1996; and Taylor, T., 'The verified elimination of nuclear warheads', *Science & Global Security*, vol. 1, nos 1–2 (1989), pp. 1–26.

fissile material production cut-off treaty, the sole multilateral initiative to limit the production of military fissile materials, further aggravates the situation.

Bureaucracy

Promoting transparency involves many complex political and technological issues that affect vested interests, including those of government departments and agencies, national legislatures and institutions. Direct and sustained attention at a high level is imperative for overcoming bureaucratic inertia and deeply rooted secrecy policies and for ensuring the necessary government coordination.

Funding

Although the NWS continue to allocate large sums of money to the maintenance and upgrading of their nuclear arsenals, strengthening transparency would result in additional financial burdens. These would be dependent on the complexity and extent of the measures to be implemented, the infrastructure necessary for undertaking them and the possible involvement of an international body. While the level of available funding would vary substantially from country to country, the state of the Russian economy is likely to continue to present serious challenges. Clearly, without foreign assistance, only limited advances could be made in Russia. Financial aid and other incentives are therefore essential preconditions for breaking down both the political and the technical barriers.

IV. Looking ahead: prospects and proposals

The prospects for immediate progress in strengthening transparency in nuclear warheads and materials appear poor. The 'comprehensive transparency regime' advocated in the second half of the 1990s by arms control scholars is unlikely to be instituted in the near future.[7] Although Russia and the USA have agreed to substantially reduce their deployed strategic nuclear weapon forces over the next decade, they have moved away from negotiated agreements and thus missed a historic opportunity to address the future of their reserve and redundant warheads. Building transparency in nuclear warheads and materials would complement and strengthen treaties imposing numerical limits on strategic nuclear delivery vehicles and the warheads attributed to them.[8] Unilateral actions, on the other hand, could result in less transparency and more reversibility. More dangerously, the existing mechanisms and accomplishments

[7] Fetter, S., 'A comprehensive transparency regime for warheads and fissile materials', *Arms Control Today*, vol. 29, no. 1 (Jan./Feb. 1999), pp. 3–7.

[8] Fetter, S. and Feiveson, H. A., 'Verifying deep reductions in nuclear forces', ed. H. A. Feiveson, *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons* (Brookings Institution Press: Washington, DC, 1999), p. 215.

could quickly be reversed, in particular if Russian–US relations become adversarial.

In spite of the difficulties, there are still windows of opportunity. In the absence of formal, binding agreements, the implementation of informal, reciprocal transparency and cooperative measures deserves attention. The USA, with its long tradition of openness and accountability, has historically been the most active proponent of transparency. Given the unrivalled military, technological and economic might of the USA, its leadership is a prerequisite for further progress.

Advancing the bilateral nuclear cooperation agenda would be one way to broadly promote transparency and overcome the legacy of the cold war. An increasingly coherent and integrated approach is necessary. This would entail the critical scrutiny of programmes currently under way as well as a stronger sense of direction and substantially increased funding. Successfully implemented initiatives, such as the 1993 Highly Enriched Uranium (HEU) Agreement, must also be accelerated. Finally, the synergies between various proposed measures—notably the monitoring arrangements connected with the 1996 Trilateral Initiative, the Mayak fissile materials storage facility and the 2000 US–Russian Agreement concerning plutonium management and disposition—should be explored further.

A more practical approach would be to revitalize the idea of pursuing phased exchanges of information on aggregate stockpiles of nuclear warheads and fissile materials on a regular basis. Early declarations, even those of a very general nature, would not only build confidence but also help to improve internal accounting systems, a welcome development in the wake of the 11 September 2001 terrorist attacks. In addition, the possibility of conducting reciprocal informal inspections on closed fissile material production facilities could be explored.

In the longer run, as the number of deployed nuclear strategic forces becomes smaller and mutual trust increases, Russia and the USA could make real and sustained progress towards practical measures to eliminate their surplus or obsolete warheads. These could be extended to cover their sizeable stockpiles of tactical nuclear weapons. The only meaningful way to impose limitations on tactical nuclear weapons would be to directly apply controls on their warheads.[9] In this regard, developments in the joint technical work to demonstrate transparent warhead dismantlement would be of vital importance.

Beyond the bilateral context, China, France and the UK, which lack the extensive technical and arms control negotiating expertise of Russia and the USA, would also need to fulfil the commitments they undertook at the 2000 Review Conference of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT) to making transparent and irreversible nuclear reductions. In addition to the recent lack of action, there are no

[9] Zarimpas, N., 'Tactical nuclear weapons', *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2002), p. 582.

signs of any short-term plans by these states to reduce their nuclear holdings. At a later stage, however, they would undoubtedly benefit from the exchanges between Russia and the USA in the search for a regime that is applicable to all the NWS. The de facto NWS, on the other hand, will not engage in any framework for nuclear transparency unless major advances are made towards eliminating regional and local tensions.

The NNWS will no doubt continue to press for greater transparency through diplomatic channels and the NPT review conferences, and through other forums such as the United Nations General Assembly and the currently deadlocked Conference on Disarmament. In general, their influence will probably remain rather limited. After the 11 September terrorist attacks and the increased nuclear proliferation threats, the NNWS are confronted by more urgent challenges than diminishing their security gap vis-à-vis the NWS and furthering disarmament. They are now understandably preoccupied with ensuring that the vast stockpiles of nuclear weapons and materials are properly accounted for and held in securely guarded installations.

Increasing and enhancing transparency in nuclear holdings will remain a difficult, complex and long-term endeavour. In the meantime, all of the NWS may find it appropriate to contemplate certain limited steps that would require neither extensive negotiations nor prohibitive costs. In addition to maintaining an active dialogue and sharing experiences, such measures would include: (*a*) reaffirming commitments to transparency and support of multilateral institutions; (*b*) preserving accomplishments and continuing to provide the necessary funding and expertise; (*c*) making voluntary stockpile declarations and transferring excess material to the civilian sector under full IAEA safeguards; and (*d*) establishing national capabilities for undertaking research and development work related to the verification of nuclear arms control and disarmament.[10]

[10] The UK is in the process of establishing such a capability. See British Atomic Weapons Establishment (note 6).

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