7. Stockpile declarations

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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/starthtm/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 Historical data on stocks, assembly, disassembly	Current aggregate stockpiles Historical data on stocks, production, consumption
2	Warhead type, delivery system Status (deployed, reserve, etc.) Historical data by type	Isotopic-grade (weapon-grade, etc.) Chemical form (metal, oxide, etc.) Physical form (pit, fuel, etc.) Historical data by grade/form
3	Inventory by declared facility Facility descriptions	Inventory by declared facility 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.