9. The changing Russian and US nuclear weapon complexes: challenges for transparency

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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

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[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]

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[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

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[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.

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[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.

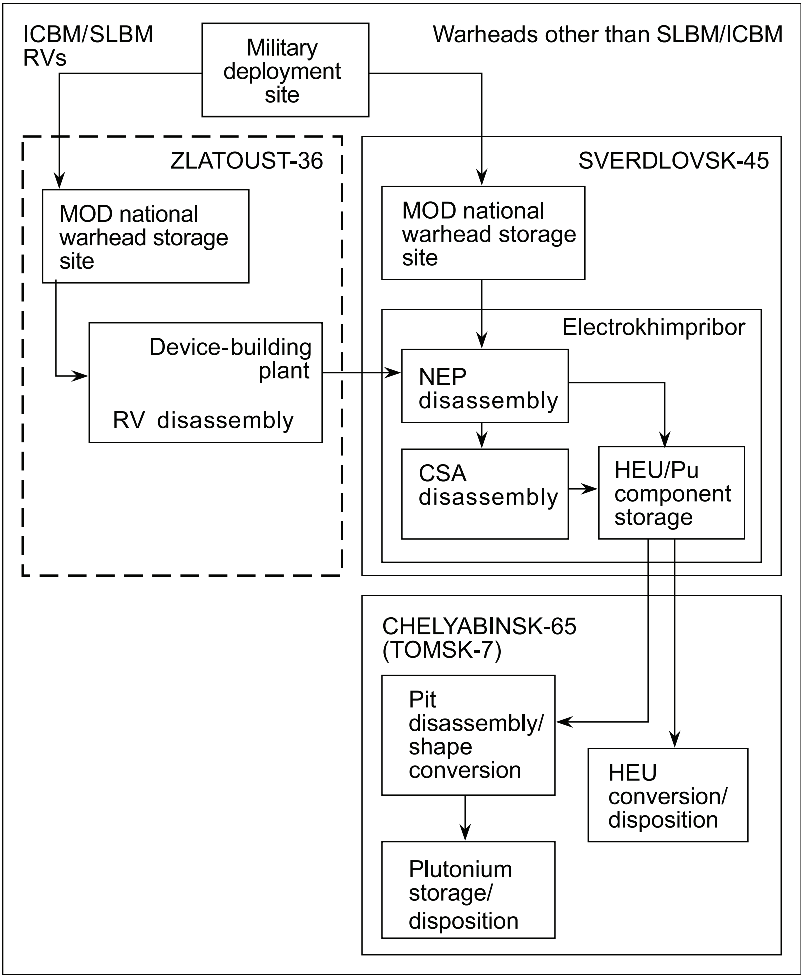

Figure 9.1. A hypothetical scenario of warhead dismantlement in Russia

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

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[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-

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[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-

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[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.

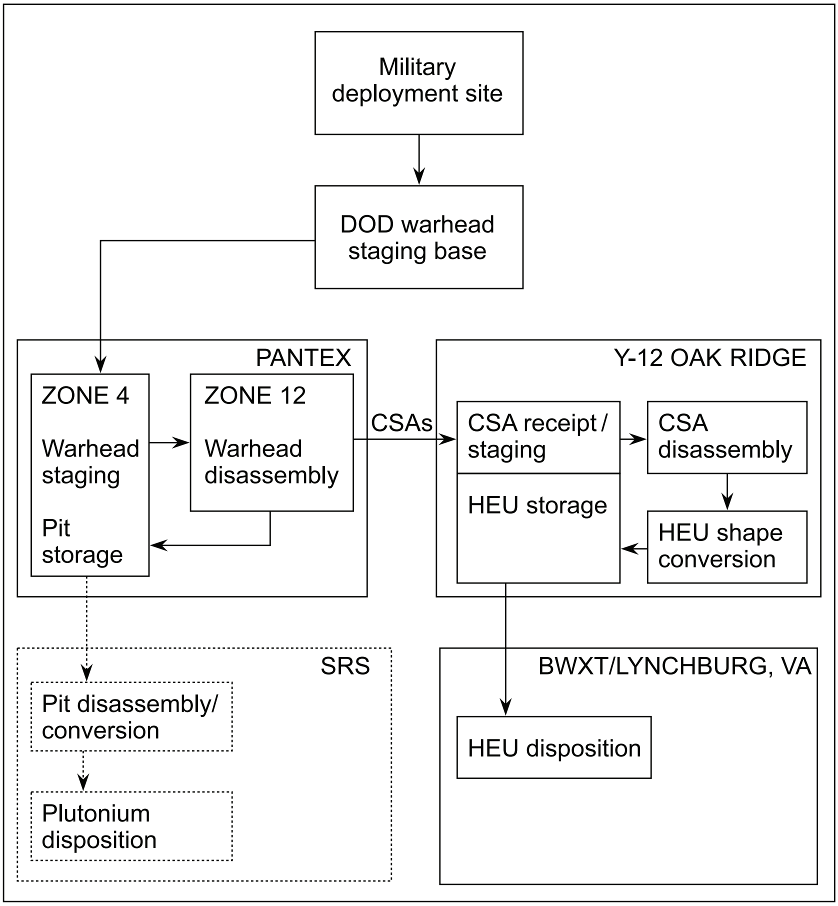

Figure 9.2. Warhead dismantlement in the USA

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

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[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-

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[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

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[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.

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[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.

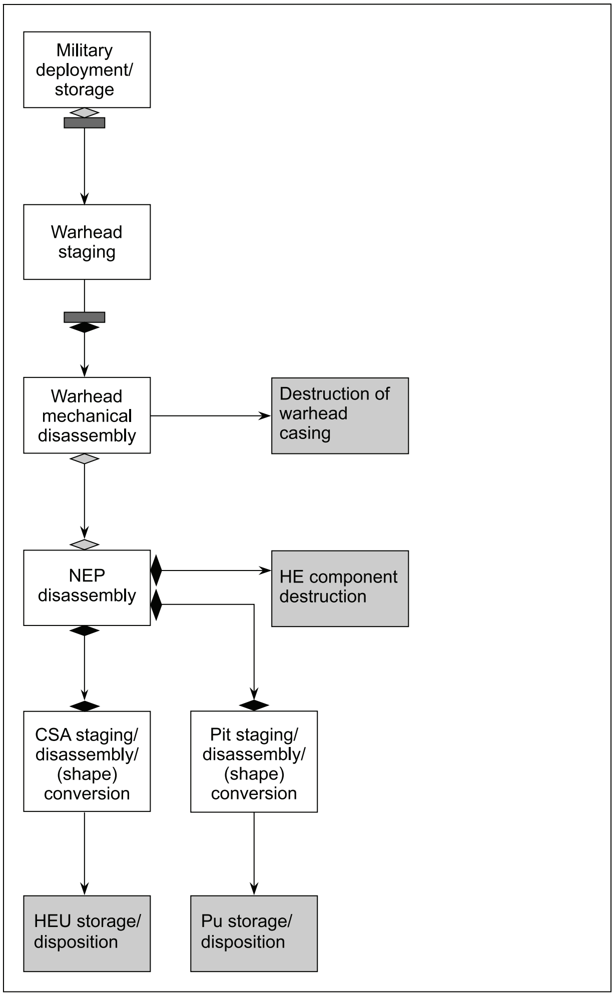

Figure 9.3. A hypothetical protocol for warhead dismantlement transparency: sequence and monitoring

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-

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[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

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[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

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[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-

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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.

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[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

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[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.