Appendix 10C. The changing Russian and US nuclear warhead production complexes

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I. Introduction

The Soviet Union (and Russia, as its successor state) and the United States have developed dedicated infrastructures to design, test, mass-produce and support field deployment of tens of thousands of nuclear warheads. During the cold war, the principal task of the Soviet and US nuclear weapon laboratories was to advance nuclear weapon science, to design and test new warheads, and to provide scientific oversight of the handling of nuclear warheads throughout their life cycle. Their production facilities dismantled obsolete warheads, modernized and refurbished warheads in the stockpile, and put into production and mass-produced warheads of more advanced types. Because of the high pace of technological innovation, nuclear warheads were often replaced before the end of their design service life. Their nuclear material production complexes produced and processed highly enriched uranium (HEU), plutonium, tritium and other essential nuclear materials. Underground nuclear explosive testing was crucial for warhead development efforts as well as for stockpile safety and reliability assurances.

The direction of nuclear weapon activities in both states changed dramatically after the cold war owing to reduced funding, the end of nuclear explosive testing and nuclear warhead stockpile reductions. The end of nuclear explosive testing by the USSR (1990) and the USA (1992) has altered the nature of warhead research and development (R&D) activities. The development of more advanced warhead designs was prohibited by the US Congress and has lost priority in Russia.[1] The USA has launched an ambitious and expensive Science-Based Stockpile Stewardship (SBSS) programme, which seeks to develop supercomputing capabilities to provide for 3-D modelling of nuclear weapons, to modernize the existing facilities and build new experimental ones, to improve the understanding of the physics of nuclear weapons, and to maintain the Nevada Test Site in a state of readiness for the resumption of nuclear explosive testing.

The US SBSS programme has been criticized as unnecessary, excessively expensive, and economically and politically motivated. In particular, according to the programme's opponents, the policy of maintaining the warhead design capability, which will be enhanced by new experimental facilities and computing tools, is misguided and dangerous from the arms control and non-proliferation standpoint.[2] On the other

[1] As of Mar. 2002, the congressional prohibition remained in effect. However, the USA has resolved to re-establish warhead advanced concept teams in its national nuclear weapon laboratories. See Statement of US Secretary of Energy Abraham Spencer before the Committee on Armed Services, US House of Representatives, 13 Mar. 2002, URL <http://www.house.gov/hasc/openingstatements andpressreleases/107thcongress/02-03-13abraham.html>.

[2] Critics of the SBSS point out that the programme would: (*a*) undermine the 1968 Non-Proliferation Treaty and the 1996 Comprehensive Nuclear Test-Ban Treaty by advancing weapon capabilities; (*b*) describe accurate models of physics processes in nuclear weapons in unclassified publications, thereby facilitating an increase in the weapon capabilities of other nations; and possibly (*c*) facilitate development of proliferation-prone pure-fusion weapons. See, e.g., Paine, C. and McKinzie, M., *Does*

side of this debate, a number of US nuclear weapon scientists and policy makers have expressed concerns about the ability of the USA to maintain the safety and reliability of its warheads without underground nuclear explosive testing.[3]

The Russian stewardship programme is significantly less costly and less ambitious in its goals. Its R&D activities are largely limited to stockpile surveillance, maintenance of nuclear warhead design skills and prevention of surprise breakthroughs in nuclear weapon developments in other states.

Warhead stockpile reductions have also deeply affected nuclear weapon activities. As a result of 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 1991–92 Bush–Gorbachev/Yeltsin Presidential Nuclear Initiatives (PNI), the decommissioning of naval ships, aircraft and other delivery systems, and the retirement of unsafe and obsolete weapons, Russia and the USA have significantly reduced their nuclear warhead stockpiles. The US active stockpile declined from 23 000 warheads of 25 types in 1985 to approximately 8000 warheads of 7 major types in 2001.[4] Nuclear warhead reductions in Russia have been even more significant, with a decline from 35 000 warheads in the mid-1980s to approximately 10 000 warheads in 2001. Reductions to approximately 5000 active warheads are projected to take place by 2010.[5]

Because of these reductions there is currently no need for new nuclear materials. The scale of new production and refurbishment of nuclear warheads has declined. The two states have undertaken a massive warhead dismantlement effort.

These changes in mission, operating environment and resources call for comprehensive restructuring and downsizing of the Russian and US nuclear warhead production complexes. Each state needs an economic, safe and secure complex consisting of a small number of compact, specialized facilities capable of providing for all critical aspects of nuclear weapon production: nuclear weapon R&D and non-nuclear explosive testing, tritium production and processing, fissile material component manufacturing, fabrication of specialized non-nuclear components and warhead assembly–disassembly. Because of their historical, economic, technical and other differences, the two states have been pursuing this objective differently and differ in the progress they have made.

the US Science-based Stockpile Stewardship Program Pose a Proliferation Threat? (Natural Resources Defense Council: Washington, DC, Nov. 1998).

[3] Glanz, J., 'Testing the aging stockpile in a test ban era,' *New York Times*, 28 Nov. 2000, p. 1.

[4] The US Nuclear Posture Review (NPR), completed in Dec. 2001, divides the US nuclear warhead stockpile into several categories. The active stockpile is composed of operationally deployed warheads and responsive force warheads. Responsive force warheads are stored in a ready-to-use configuration and can be deployed in a period ranging from weeks to one year or more. The responsive force stockpile is intended to ensure a flexible force that could be reconstituted in response to changing national security and threat environments. There is also an inactive stockpile, which is largely intended to replace catastrophic failures of similar warheads. US Department of Defense, Transcript of special briefing on the Nuclear Posture Review, 9 Jan. 2002, available at URL <http://www.defenselink.mil/news/Jan2002/t01092002_t0109npr.html>. For more detail on the NPR see appendix 10A in this volume. It is believed that, instead of irreversibly eliminating warheads removed from delivery systems according to the Nov. 2001 declarations by presidents Bush and Putin, the USA would shift a large fraction of the removed warheads to its responsive force or inactive stockpile. 'The Bush–Putin summit: in 2 leaders' words: cordial discord', *New York Times,* 16 Nov. 2001, p. A12; and Natural Resources Defense Council, 'Faking nuclear restraint: the Bush Administration's secret plan for strengthening US nuclear forces', Press Release, Washington, DC, 13 Feb. 2001, available at URL <http://www.nrdc.org/media/pressreleases/020213a.asp>.

[5] There is no public information on the number of warhead types in the Russian arsenal.

Sections II and III of this appendix review the efforts and progress made by Russia and the USA, respectively, in restructuring their nuclear warhead production complexes.

II. The Russian complex

At present, the Russian nuclear warhead production complex is managed by the Ministry of Atomic Energy (Minatom) and consists of 17 research institutes and manufacturing facilities (see table 10C.1).[6] The core functions of the complex—production and processing of nuclear materials, nuclear warhead R&D and assembly–disassembly of nuclear warheads—are located in 10 'closed cities'. (There are also numerous research institutes and production facilities in Moscow and other 'open cities'.) The existence of the closed nuclear cities was not officially acknowledged until 1992 and their present status is that of closed administrative–territorial units. The cities are surrounded by double fences that are patrolled by armed guards. Access is limited and thoroughly controlled. The main purpose of stringent security arrangements is to protect the secrecy of sensitive nuclear operations and to prevent terrorist attacks against them. The cities currently have a combined population of approximately 760 000 people, of whom 130 000 work at nuclear facilities (half of them on civilian projects).

Unlike the US complex (see section III), the Russian complex has a complete set of nuclear warhead production facilities. The complex remains oversized and much of its R&D and production infrastructure is redundant. The downsizing of the complex, however, is inevitable. The strategic rationale for maintaining a massive weapon production infrastructure has been relegated to the past. Moreover, the Russian economy is no longer capable of supporting the cold war complex. In fact, its technical infrastructure has already been contracting because of ageing and lack of maintenance while its pool of scientific and technical talent has been shrinking because of demographic shifts and economic conditions. Minatom's nuclear weapon workforce has been reduced from approximately 130 000 workers in the late 1980s to approximately 75 000 workers at present, and several facilities no longer perform nuclear weapon functions.

Nuclear weapon complex reductions: the early years

Cuts in the nuclear weapon programme began in the late 1980s. The initial phase of downsizing lasted approximately 10 years and can be characterized by the following three developments: the termination of HEU and plutonium production for weapons; defence conversion without complex restructuring; and spontaneous contraction of weapon capabilities.

[6] The weapon complex's facilities are managed by 3 Minatom departments: the Nuclear Fuel Cycle Department (formerly the Fourth Main Directorate), the Nuclear Weapons Development and Testing Department (formerly the Fifth Main Directorate), and the Department of Nuclear Weapons Production (formerly the Sixth Main Directorate). Another facility of the complex, the Novaya Zemlya Test Site, is managed by the Ministry of Defence.

Table 10C.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 Avtotransportnogo 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
Production Association ‘Sever’ (Proizvodstvennoye Obyedinenie ‘Sever’)	Novosibirsk	Production of non-nuclear weapon components

Facility English (Russian) name	Location (old name if applicable)	Nuclear warhead production functions
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
Nizhneturinsky 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).

The termination of defence orders for new fissile materials effectively excluded the uranium enrichment and plutonium production plants from the weapon programme.[7] As a result, no nuclear weapon activities presently take place in three of the closed nuclear cities: Novouralsk, Zelenogorsk and Zheleznogorsk. However, other activities in these cities remain critical to the mission of storing and managing hundreds of tonnes of fissile materials, some of which could be a part of Russia's strategic reserves.

In the late 1980s, the Soviet Government also developed a number of defence conversion programmes to redirect excess workers and equipment to civilian work. However, most defence conversion efforts have failed because of insufficient investment, the collapse of Russia's domestic markets, the lack of entrepreneurial and market skills, secrecy, inflexible institutional bureaucracies and high production costs. As a result, the reductions have been largely spontaneous. Although the infrastructure deterioration and personnel attrition have already made the complex much less capable, with the exception of the separation of the HEU and plutonium production facilities, it has not changed structurally.

The 1998 programme and its implementation

It was not until after the mid-1990s that Minatom and facility managers accepted the fact that weapon programme cutbacks were irreversible and that a serious restructuring and downsizing effort was needed for the complex to survive in the new environment. Such an effort was launched, and it appears that its main objective is to focus defence order funds by reducing facility duplication and by separating the defence part of the complex from the part that has become excess to defence requirements. The process of separation involves the establishment of separate lines of funding (state defence budget for defence facilities versus revenues from commercial sales for civilian parts) and management, division of the production and support infrastructure, and consolidation of remaining defence activities inside isolated buildings and/or

[7] Instead, they provide uranium enrichment and spent fuel management services to domestic and international customers and are involved in a variety of other nuclear and non-nuclear commercial activities. All of these facilities, with the exception of the plutonium production centre in Zheleznogorsk, are also involved in the HEU down-blending work under the 1993 US–Russian HEU Agreement, reproduced in *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), pp. 673–75.

technical areas. The second and companion objective is to create civilian jobs for excess personnel.

Minatom's plans were formalized in the programme 'On Restructuring and Conversion of the Nuclear Weapons Complex in 1998–2000', adopted by the Russian Government in June 1998 as a part of a broader plan to restructure Russia's defence industries.[8] The programme and other planning documents call on Minatom to: (*a*) stop warhead assembly at the serial production facilities in Sarov and Zarechny by 2000; (*b*) stop warhead dismantlement at these two facilities by 2003; (*c*) transfer the production of certain non-nuclear warhead components and assemblies to the pilot production plants of the warhead R&D institutes by 2000; (*d*) consolidate weapon work at the remaining non-nuclear component manufacturing facilities by 2000; (*e*) phase out nuclear weapon work at one of the two fissile material processing plants in 2003; (*f*) cut the number of defence programme personnel from 75 000 to 35 000 by 2005;[9] and (*g*) cut the number of defence personnel at the serial production plants from 71 000 during the cold war to approximately 11 000 within the next several years.

Downsizing is also planned for individual facilities and would involve defence personnel reductions and consolidation of weapon activities in fewer buildings and production areas. For example, the number of defence programme personnel at the warhead assembly facility in Trekhgorny was to decrease from 5766 in 1997 to 2800 in 2001.[10] At the Urals Electromechanical Plant in Yekaterinburg, which produces nuclear warhead electronic components, the plan is to split the facility into two separate entities.[11] The weapon part would be located in a single building and would retain about one-third of the equipment and infrastructure. It would be supported exclusively by defence-order funding. The remainder of the plant would have to support itself by producing and selling commercial products on the open market. The number of personnel employed in the weapon programme would decline from the cold war level of 12 000 to 1500.

Certain steps have already been taken. In April 1999 Minatom formed the Department for Conversion of the Nuclear Industry, which has the responsibility for defence conversion and complex restructuring.[12] All research institutes and production plants of the warhead complex have made progress and are working to implement facility level restructuring programmes. Essentially no weapon work is taking place at the Molnia plant in Moscow. The production association Sever in Novosibirsk, a nuclear warhead electronic components and sub-assemblies production facility, has already consolidated all weapon work in a single technical area and reduced defence pro-

[8] The programme was announced for the first time by Minatom's First Deputy Minister Lev Ryabev at the 7th Carnegie International Nonproliferation Conference, 11–12 Jan. 1999, Washington, DC. See Ryabev, L., 'The role of the NCI in meeting Russia's nuclear complex challenges', available at URL <http://www.ceip.org/files/events/conf99ryabevslides.asp>, where there is also a complete list of remarks and presentations from the conference.

[9] According to Minatom's First Deputy Minister Lev Ryabev, the total number of workers at Minatom's facilities in the 10 closed cities is *c.* 150 000. This presumably includes workers in transport, utilities and other support divisions. Many of these divisions have recently been transferred to municipal control. Bukharin, O. *et al.*, *Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities* (Program on Nuclear Policy Alternatives, Princeton University: Princeton, N.J., June 2000).

[10] ['Trekhgorny's plans'], *Atompressa*, no. 13 (Apr. 1999), p. 3 (in Russian).

[11] Sachkova, S., ['Hopes of defence workers'], *Atompressa*, no. 46 (Dec. 1999), p. 3 (in Russian).

[12] See, e.g., ['Conversion: interview with A. Antonov'], *Atompressa*, no. 1 (Jan. 2000), pp. 1–2 (in Russian).

gramme staff.[13] This facility is projected to lose its weapon functions some time between 2005 and 2007. Warhead assembly work was terminated at the Avangard plant in Sarov and its primary weapon function at present is warhead dismantlement.[14] The Zarechny warhead production facility reportedly has very few defence orders.[15] Seversk has also essentially become a civilian nuclear technology centre. Already, the bulk of the workload at the chemical and metallurgical plant in Seversk, which in the past produced HEU and plutonium components of nuclear warheads, is non-military and is related to HEU down-blending under the 1993 US–Russian HEU Agreement. Finally, the pilot plants at the nuclear warhead design institutes of the All-Russian Scientific Research Institute of Experimental Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Eksperimentalnoy Fiziki, VNIIEF) in Sarov, the All-Russian Scientific Research Institute of Technical Physics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Tekhnicheskoy Fiziki, VNIITF) in Snezhinsk, and the All-Russian Scientific Research Institute of Automatics (Vserossiyskiy Nauchno-Issledovatelskiy Institut Avtomatiki, VNIIA) in Moscow are assuming responsibility for the production of certain components and assemblies that in the past were manufactured by serial facilities.

The USA and other Western countries have launched several cooperative programmes that facilitate the downsizing of the Russian nuclear complex.[16] The most significant of them is the US–Russian HEU Agreement, which provides the primary source of funding for Minatom to conduct complex conversion and downsizing activities.[17] In addition, the HEU down-blending process involves thousands of workers in the closed cities. The International Science and Technology Centers (ISTC), the Cooperative Threat Reduction (CTR) programme and other cooperative efforts also provide productive work for nuclear weapon experts. Of particular note is the Nuclear Cities Initiative (NCI), which was established by the US Department of Energy (DOE) in 1998 and is intended specifically to facilitate the downsizing of the Russian nuclear weapon complex.[18] Each of these cooperative programmes has made a positive contribution. However, their effect so far has been limited and it is clear that most of the job remains to be done.

Problems of downsizing and restructuring

A rational approach to optimizing Russia's warhead complex would be to consolidate weapon work at the smallest number of facilities possible. It would be based on a cost-benefit analysis of the existing infrastructure, future missions, and stockpile and funding projections. In reality, however, there are many other factors that could influ-

[13] Gorb, A., ['PO "Sever" in the program of restructuring and conversion of the nuclear industry'], *Atompressa*, no. 1 (Jan. 2000), p. 3 (in Russian).

[14] The assembly of the last warhead at the Avangard Plant was finished on 30 Dec. 1997. See Zavalishin, Yu., [*'Avangard' Atomic*], (Krasny Oktyabr': Saransk, 1999), p. 292 (in Russian).

[15] Saratova, L., ['How do you live, you weapons plant?'], *Gorodskoy Kuryer*, no. 3 (23 Jan. 1999) (in Russian), available at URL <http://courier.sarov.ru>.

[16] For a discussion of international assistance programmes in the closed nuclear cities see Bukharin *et al*. (note 9).

[17] According to the 1993 US–Russian HEU Agreement, the USA agreed to buy 500 t of excess weapon-grade HEU after it had been blended down to 4–5% enriched uranium for use in nuclear power reactors.

[18] Kile, S., 'Nuclear arms and non-proliferation', *SIPRI Yearbook 2000: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2000), pp. 457–62; and chapter 10 in this volume.

ence Minatom's ability to plan and execute the downsizing and restructuring of the complex.

The most significant near-term problem is the redirection of excess workers. Downsizing, particularly in the closed nuclear cities, is not possible unless new jobs or other opportunities are created for displaced nuclear weapon workers. Indeed, massive lay-offs in the closed cities would threaten their social stability and increase the danger of thefts of nuclear materials or proliferation of weapon expertise. Minatom estimates that it needs to create approximately 35 000 jobs in the closed cities by 2005.

Defence conversion and job creation in the closed cities are challenging tasks. Their isolation, security restrictions, lack of modern communications and other business infrastructure and, at some locations, radioactive contamination, make the development of normal business relationships difficult. The crisis of the Russian economy and insufficient foreign investment will also continue to inhibit defence conversion at Minatom facilities and economic development in the local communities. Workforce reductions due to retirement, personnel losses to the commercial sector and minimal new hiring will hopefully relieve this pressure in five to ten years. However, massive retirement would increase the social protection and pension needs of workers in the nuclear complex.

Funding shortages constitute another critical problem. Minatom estimates that it will cost approximately $1 billion to implement the planned reductions.[19] About one-half of the cost would be for consolidation and clean-up; the rest would be for creating jobs for displaced workers. Generally, until the national economy recovers, making rapid progress on complex downsizing might prove difficult.

The pace of downsizing will also depend on domestic politics in Russia. A decision to terminate defence orders at a large production facility, especially in a closed city, would be politically unpopular (unless attractive non-military jobs were created) and would encounter opposition from facility workers, local communities, regional authorities and the Russian Duma. Pressure from these groups, compounded by anti-Western sentiment and nationalism, is likely to slow down the downsizing process.

Finally, complex downsizing could be complicated by strategic uncertainties. These include the USA's plans to keep many warheads in storage after they have been removed from strategic delivery systems and the US Senate's rejection of the 1996 Comprehensive Nuclear Test-Ban Treaty[20] (CTBT, not in force). In the absence of irreversible arms reductions, the Russian Government will be under pressure to maintain a 'national emergency' option of rebuilding its nuclear stockpile to cold war levels and of resuming massive warhead R&D efforts. There have already been proposals to initiate a weapon R&D effort aimed at countering the potential deployment of a strategic missile defence system in the USA.

These difficulties are serious. They could slow down, or even derail, the downsizing of the nuclear warhead complex unless the Russian Government and the international community provide strong political support, leadership and sufficient funding.

[19] Remarks by Minatom's Deputy Minister Lev Ryabev at an international conference, Helping Russia Downsize its Nuclear Complex, Princeton University, Princeton, N.J., Mar. 2000, documented in Bukharin *et al*. (note 9).

[20] For details of the treaty see URL <http://www.clw.org/pub/clw/coalition/ctbindex.htm>.

Beyond planned reductions

Although ambitious, the planned reductions may result in a complex that is still oversized relative to Russia's future nuclear defence missions and economic resources.[21] Further reductions of the warhead production infrastructure, therefore, could be expected in the future.[22] All warhead re-manufacturing and surveillance operations, for example, could be consolidated at one facility (most likely in Lesnoy). Deep reductions in nuclear arms by the five nuclear weapon powers recognized by the 1968 Non-Proliferation Treaty (NPT) would make it possible in a more distant future to further consolidate all warhead production and maintenance activities into the warhead design institutes in Sarov and Snezhinsk. In that case, Lesnoy would focus on warhead dismantlement and later be adapted for civilian purposes.

III. The US complex

The US nuclear warhead production complex is managed by the Office of Defense Programs of the National Nuclear Security Administration (NNSA), a semi-autonomous organization within the Department of Energy (DOE). In the mid-1980s, just prior to the end of the cold war, the complex consisted of 12 facilities and employed approximately 70 000 workers (see table 10C.2).[23] The downsizing of the complex began in the late 1980s. In 1988 and 1989, in the aftermath of the Chernobyl disaster in the Soviet Union, the DOE shut down its remaining tritium and plutonium production reactors at the Savannah River, South Carolina, and Hanford, Washington, sites. (The production of HEU for nuclear weapons in the USA stopped in 1964.) Also in 1989, the production of plutonium pits was terminated at the Rocky Flats Plant outside of Denver, Colorado, because of environmental and safety concerns.

The US industrial infrastructure for mass production of nuclear warheads has further contracted during the 1990s. In 1994 the DOE terminated the remaining weapon functions at the Rocky Flats Plant and declared the facility to be an environmental management site. In 1995 the DOE closed the Pinellas Plant near St Petersburg, Florida, and the Mound Laboratory near Miamisburg, Ohio. Many of their warhead production and management activities have been consolidated to the Kansas City Plant or transferred to the DOE's national laboratories. The weapon programme workforce has declined as of 2001 to approximately 25 000 workers and many former weapon workers have been transferred to environmental clean-up on non-proliferation work.

The US nuclear warhead complex currently consists of eight facilities.[24] The complex is projected to retain its current structure in the foreseeable future with consoli-

[21] Minatom is currently working on a new complex restructuring plan extending to 2010 but its contents have not been yet made public. See ['Notable dates and events in Minatom—2000'], *Atompressa*, no. 49–50 (Dec. 2000), p. 5 (in Russian).

[22] For an analysis of downsizing options for the Russian nuclear warhead 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: Princeton, N.J., May 2000).

[23] For a general description of the US nuclear warhead complex during the cold war see Cochran, T. *et al.*, *US Nuclear Warhead Facility Profiles*, *Nuclear Weapons Databook, Vol. III* (Ballinger: Cambridge, Mass., 1987). Table 10C.2 does not include facilities that were not directly involved in nuclear weapon production work.

[24] The present status of the US weapon complex is discussed in US Department of Energy, *FY 2000: Stockpile Stewardship Plan*, Sanitized Version (DOE Office of Defense Programs: Washington, DC, 15 Mar. 1999).

Table 10C.2. The US DOE nuclear warhead production complex, 2001

Facility/location	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 nuclear explosive packages (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 highly explosive (HE) components Storage of plutonium pits
Oak Ridge Y-12 Plant	Oak Ridge, Tennessee	Surveillance of thermonuclear canned secondary sub-assemblies (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	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

[a] In addition to pits, 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).

dation of nuclear weapon activities and restructuring taking place within individual facilities. According to NNSA officials, the complex needs a major investment in order to maintain and improve the basic infrastructure of individual facilities (buildings, roads, utilities, etc.).

Although the US weapon production capability has been reduced, it remains 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.[25] Other key DOE facilities also maintain a sizeable production capacity.[26]

The USA currently lacks a source of new tritium. Tritium is an essential component of all modern thermonuclear (and presumably fission) weapons. Tritium–deuterium gas is used to boost the yield of the fission primary to make it powerful enough to ignite the thermonuclear secondary. Because it decays at a rate of approximately 5.5 per cent per year, there is a need for periodical removal of helium, the decay product, and for replenishment of tritium stocks. In this context the 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms (START II Treaty), which is not in force, can be mentioned. According to the DOE, in order to maintain a five-year reserve of tritium without the treaty's entry into force the USA would need to resume the production of tritium in 2005. In December 1998 the DOE decided to

[25] 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-only capacity is 250–350 warheads per year. See US Department of Energy (note 24).

[26] 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 tritium recycling/reloading of 2500 reservoirs per year, compared to 6000 reservoirs per year in the past. See US Department of Energy (note 24).

use the commercial nuclear power reactors of the Sequoyah and Watts Bar nuclear power plants in Tennessee for these purposes.[27]

The USA also currently lacks an industrial-scale capability to produce plutonium pits. This might not be an obstacle, however. The Los Alamos National Laboratory, the only US facility with complete plutonium-handling capabilities, is expected by 2007 to reach a manufacturing capacity of 20 pits per year. Eventually, it could 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 such a facility.[28] The conviction that such a contingency plan is needed is largely based on incomplete scientific knowledge about plutonium ageing, uncertain predictions about pit longevity and the possibility of common-mode failure mechanisms that could render inoperative a large fraction of the warhead stockpile. There are also proposals within the DOE to build a new state-of-the-art uranium-processing facility to replace the ageing facilities of the Oak Ridge Y-12 plant in Tennessee.

Future deep arms reductions might lead to further contraction of the complex, including a transfer of certain production functions to national weapon laboratories and a closure of some facilities. For example, for a stockpile of a few hundred weapons, warhead maintenance and refurbishment operations eventually could be moved to the Device Assembly Facility (DAF). Located at the Nevada Test Site, DAF is a state-of-the-art safe and secure facility that was originally designed to assemble nuclear explosive devices for underground testing; it is now primarily used to support the DOE's subcritical experiments and for training.[29] It has Pantex-style warhead assembly–disassembly bays and cells, and staging areas for warhead and nuclear component storage.[30]

IV. Conclusions

The end of the cold war called for the radical downsizing and restructuring of the Russian and US nuclear warhead production complexes. The Russian complex, although smaller compared to its size during the cold war, remains oversized. The implementation of Russia's downsizing plans has been slow because of insufficient funding and difficulties in finding alternative employment for displaced nuclear weapon workers. The USA has already concluded the first phase of its infrastructure reductions. However, the US decision to rely on the SBSS programme for stockpile maintenance, the US Senate's rejection of the CTBT and the US policy of maintaining a large reserve of non-deployed warheads as well as plutonium pits could have a negative impact on non-proliferation and future arms reductions.

Future nuclear arms reductions in Russia and the USA would call for further downsizing and restructuring of their respective nuclear warhead production infra-

[27] 'Secretary certifies nuclear stockpile; selects tritium source, pit disassembly sites', *DOE This Month*, Jan. 1999, p. 3.

[28] See US Department of Energy (note 24), chapter 12, p. 8.

[29] '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>.

[30] Disassembly cells are used to conduct operations with uncased explosives and fissile material components. Should conventional explosives detonate, disassembly cells are designed to vent such an explosion and trap fissile materials. Operations with uncased insensitive high explosives and nuclear materials may be performed inside a disassembly bay.

structures. Under deep stockpile reductions, for example, most nuclear warhead operations could be consolidated at pilot-scale facilities associated with nuclear weapon R&D laboratories.

High-level policy support and technical cooperation between the two countries on complex downsizing and restructuring, and international cooperation to facilitate the contraction of the Russian complex, must become integral elements of the downsizing effort. The Russian–US nuclear relationship will be a major determinant in the reshaping of the national weapon complexes. Greater transparency in nuclear activities in both countries and expanded cooperation are thus critical for developing rational post-cold war policies.