Science and Global Security, 10:103–124, 2002

0892-9882/02 $12.00 + .00
DOI: 10.1080/08929880290008449

Verification of the Shutdown or Converted Status of Excess Warhead Production Capacity: Technology Options and Policy Issues

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Russia's Ministry of Atomic Energy has announced that nuclear warhead assembly and disassembly will be phased out at two out of four existing facilities. Arms reductions could result in a closure of additional facilities in Russia and other nuclear weapons states. A transparency regime to monitor their shutdown or converted status could become an important element of future arms control and nonproliferation initiatives as well as a possible element of the emerging U.S.-Russian nuclear security partnership. This article explores possible approaches to monitoring former warhead assembly facilities and discusses anticipated difficulties of implementing such a transparency regime.

INTRODUCTION

Nuclear weapons reductions after the Cold War have made redundant parts of the U.S. and Russian nuclear warhead production infrastructures. These excess facilities need to be either closed or cleaned out and redirected to missions other than nuclear weapons production. Several future cooperative nuclear security initiatives may include international monitoring and transparency

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Received 3 December 2001; accepted 15 May 2001.

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measures to assure that such facilities are no longer used to manufacture nuclear weapons.

For example, for several years, U.S. and Russian technical experts have been jointly developing technologies and procedures that potentially could be used to monitor dismantlement of nuclear weapons. Because Russia has a much larger warhead production complex (four warhead assembly facilities versus one in the United States) some arrangements to account for new warhead production and to monitor the shutdown of production capacity might become an essential element of a future agreement to confirm data on warhead and fissile material stocks. Such measures would reduce U.S. concerns that Russia might use its huge warhead production complex to quickly expand its warhead arsenal in a break-out scenario during a period of increased international tension.

In particular, the Electromechanical plant “Avangard” in Sarov (formerly Arzamas-16) and the Production Association START in Zarechny (Penza-19), two of Russia’s four serial warhead production plants, are to phase out nuclear weapons production and could be potential targets for monitoring. Avangard and START have already reportedly ceased assembling new weapons and Russia’s Ministry of Atomic Energy (Minatom) announced plans to finish warhead dismantlement work at these facilities by 2003.

Transparency of nuclear weapons production would be particularly important for future deep arms reductions. Stockpile reductions to the level of hundreds of warheads would likely require an international arms control agreement between the five recognized nuclear weapons states that would call for parallel and verifiable reductions of nuclear arsenals and the corresponding production infrastructures. Small nuclear stockpiles could be supported by relatively small manufacturing facilities, which, for example, could be associated with national nuclear weapons R&D centers. Industrial-scale warhead production facilities would be shut down and would have to be verifiably dismantled or monitored to assure that the arms reductions process is not circumvented.

If such multilateral agreements strictly limiting nuclear arms were reached in the future, the methods and technologies developed to monitor the shutdown of weapons facilities in the United States or Russia could become a valuable model for other states to follow.

This article seeks to explore approaches to monitoring known former warhead assembly facilities. Using the examples of former and operating weapons production facilities in the United States and Russia, the article discusses possible objectives of such a transparency regime and anticipated difficulties of its implementation.

NUCLEAR WARHEAD ASSEMBLY/DISASSEMBLY FACILITIES

What constitutes a warhead assembly/disassembly facility and under what circumstances could it be considered “shutdown” or “converted”? The United States, Russia, and other nuclear weapons states have each developed dedicated safe and secure facilities for nuclear warhead assembly and disassembly operations (see Table 1). These facilities are critical elements of national nuclear weapons infrastructures.[1] Their broad operational responsibilities include the production of new warheads, the dismantlement of retired warheads, warhead modernization and refurbishment, stockpile surveillance and component testing, production of trainers, and modification of stockpiled warheads for flight-testing purposes (an operation involving replacement of fissile components with inert materials and telemetry systems).

For the purpose of this discussion, a facility is defined as a nuclear warhead assembly/disassembly plant if it conducts the operations of assembly (disassembly) of nuclear explosive packages (NEP, an assembly containing high-explosive, HE, components and fissile materials), and/or final mechanical assembly of warheads (bombs).[2] Because such operations involve staging and handling of fissile material components and assemblies (including NEPs and fully assembled warheads), the facility’s status could be defined as “shutdown” or “converted” if it no longer works with intact nuclear weapons or subassemblies containing fissile materials. A facility, however, could remain an active industrial site with parts of its former nuclear weapons production equipment and infrastructure used to produce conventional munitions or other high-technology products.

The proposed definitions appear appropriate for the known “serial” production facilities in the United States, Russia, and other countries with mature nuclear weapon technologies. Nuclear stockpiles of these countries are composed of “sealed-pit weapons,” in which fissile-material containing components are integral to a warhead system. The definition would not work for countries (if any) with less-advanced nuclear weapons technologies that rely on the separation of fissile material components from conventional explosives for safety and security purposes. In this case, warhead assembly facilities would produce “complete weapon subassemblies”—full assemblies of nonnuclear and HE components minus nuclear capsules. (Nuclear capsules would be inserted into the warheads just before use.)

The definitions also assume that the production of nuclear components and warhead assembly operations take place in different locations. This assumption appears valid in most practical, policy-relevant situations (particularly as far as the production of plutonium components is concerned). There are,

Table 1: Known nuclear warhead assembly/disassembly facilities worldwide.

Name/location	Status/years of operation	Past and present warhead operations	Current and planned activities for shutdown/converted facilities; other relevant information
United States			
SNL TA-2/Albuquerque, NM	Shutdown/1948–59	Complete weapon subassembly assembly	Not used
Burlington AEC plant/ Burlington, IA	Shutdown/1948–75	HE component production; final assembly	Manufacturing of conventional munitions
Medina base mod center/San Antonio, TX	Shutdown 1958–66	Modifications; refurbishments	Currently Lackland AFB Gravel Gerties not used; magazines used to store conventional munitions
Clarksville mod center/Ft Campbell, KY	Shutdown 1960–1965	Modifications; refurbishments	Currently Ft Campbell Army base Gravel Gerties not used; magazines used to store conventional munitions
Pantex/Amarillo, TX	Operating 1951–present	HE components production; final assembly; stockpile surveillance; production of flight-testing units	
Device Assembly Facility/Nevada Test Site, NV	Operating 1995–present	Support to underground testing; damaged/ foreign warheads	Underground facility not used for war reserve warhead assembly
Russia			
Electromechanical plant avangard/ Arzamas-16 (Sarov)	Operating 1951–present	Final assembly; nonnuclear component manufacturing; radioisotopes	New production phased out dismantlement stop in 2001–03 Future: civilian production, conventional weapons, warhead components
PO Start/Penza-19 (Zarechny)	Operating 1955–present	Final assembly; nonnuclear component manufacturing	New production phased out dismantlement stop in 2003 Future: civilian production, warhead components
ElectroKhimPribor/ Sverdlovsk-45 (Lesnoy)	Operating late 1950s–present	Final assembly; stockpile surveillance; nonnuclear component manufacturing	

Table 1: Known nuclear warhead assembly/disassembly facilities worldwide. *(Continued)*

Name/location	Status/years of operation	Past and present warhead operations	Current and planned activities for shutdown/converted facilities; other relevant information
Device-building plant/ Zlatoust-36 (Trekhgorny)	Operating 1955–present	Final assembly; stockpile surveillance; nonnuclear component manufacturing	
VNIIEF communist plant/ Arzamas-16 (Sarov)	Operating na	Experimental and testing warheads; technology development	Pilot facility
VNIITF plant 2/ Chelyabinsk-70 (Snezhinsk)	Operating na	Experimental and testing warheads; technology development	Pilot facility
Great Britain[1]			
AWE Burghfield/ Reading, Great Britain	Operating 1954–present	Final assembly; stockpile surveillance	
France[2]			
Ile Longue/Finistère, France	Operating na	Final warhead assembly; stockpile surveillance	
Le Ripault/Indre-et-Loire, France	Shutdown na	HE assemblies; final warhead assembly	Production of HE assemblies for nuclear weapons continues
CEA-Valduc/Cote-d’Or, France	Shutdown na	Nuclear components; final warhead assembly	Production of nuclear components continues
Plateau d’Albion/ France	Shutdown na	Final warhead assembly	Na
China[3]			
Jiuquan Atomic Energy Complex (Plant 404)/ Subei, Gansu, China	Operating na	Nuclear component fabrication; final assembly	
Lop Nur Nuclear Weapons Test Base/Xinjiang, China	?	Test device assembly	Possibly underground facility
Plant 821/Guangyuan, Sichuan, China	?	Na	
Harbin, Heilogiang, China	?	Na	

(Continued on next page)

Table 1: Known nuclear warhead assembly/disassembly facilities worldwide. *(Continued)*

Name/location	**Status/years of operation**	**Past and present warhead operations**	**Current and planned activities for shutdown/converted facilities; other relevant information**
Undeclared nuclear weapons states[4]			
Yodefat/Haifa, Israel	Operating 1966–present	Nuclear components; final assembly	Underground facility
Kentron Circle-Advena/Pelindaba, South Africa	Shutdown 1981–1989	Nuclear (HEU) components; final assembly	Light commercial use

[1] R. S. Norris, A. S. Burrows, R. W. Fieldhouse *British, French, and Chinese Nuclear Weapons*, Nuclear Weapons Databook, Volume V, Westview Press: Boulder, CO, 1994.

[2] Mary Byrd Davis *Nuclear France: Materials and Sites* (www.francenuc.org/en_chn).

[3] R. S. Norris, A. S. Burrows, R. W. Fieldhouse *British, French, and Chinese Nuclear Weapons*, Nuclear Weapons Databook, Volume V, Westview Press: Boulder, CO, 1994; *Federation of American Scientists: Nuclear Forces Guide* (www.fas.org/nuke/guide/index.html).

[4] For data on the Israeli warhead production infrastructure see *Federation of American Scientists: Nuclear Forces Guide* (www.fas.org/nuke/guide/index.html). The South African facility is discussed in detail in D. Albright *South Africa's Secret Nuclear Weapons*, ISIS, 1994. India and Pakistan, although assumed to have a nuclear weapons capability, are not known to have manufactured warheads for their respective stockpiles.

however, exceptions and the proposed definitions would have to be validated in each particular case. For example, the Jiuquan Atomic Energy Complex in China is believed to manufacture nuclear components as well as assemble nuclear warheads. Some Russian serial warhead assembly/disassembly facilities are also known to have conducted uranium processing operations.[3] Finally, smaller pilot-scale and R&D facilities could be expected to have a capability both to manufacture fissile material components and assemble small numbers of warheads.

DETECTION AND MONITORING OPTIONS

All nuclear weapons contain fissile materials and conventional explosives. Monitoring measures to detect operations with these materials could be a central element of a transparency regime. The operations of warhead assembly and disassembly, when performed on a significant scale, also have a number of other signatures, several of which could be observed by overhead surveillance and/or during on-site inspections.[4] Some of them, for example, coming and going of trucks and trains, could be attributable to continuing industrial activities; others, however, are specific to nuclear weapon operations. Monitoring and analysis of these signatures could have a useful complementary role or could be used as a primary monitoring technique if more intrusive verification measures are not acceptable for security or other reasons.[5]

The goal of monitoring would be to detect fairly significant levels of warhead production (possibly tens of warheads per year) at a known facility. For low levels of clandestine production (several warheads per year), a more credible cheating scenario, which is outside of the scope of this analysis, would be to assemble warheads at a small undeclared facility that is hidden within an unmonitored large industrial or military complex.[6]

Any monitoring arrangement would benefit from initial facility declarations. Such declarations, which could be confirmed by initial on-site familiarization visits, could include information on a facility's functions (for example, high-explosives production, production of warhead primary and secondary subassemblies, final warhead assembly etc.), organization, and layout. In particular, they would specify buildings and areas containing critical infrastructure and operations and the facility's production capacity. Information about capacities of other shutdown and operational warhead production facilities would also be very valuable.

This article considers six major monitoring options for former warhead assembly/disassembly facilities (Table 2) that could be used in combination with

Table 2: Monitoring of former warhead production facilities.

Monitoring technique	**Applications**
Infrastructure demolition	Destruction of warhead assembly cells.
Portal perimeter continuous monitoring (PPCM)	Detection of plutonium/HEU shipments.
Environmental monitoring (sampling and analysis) of soil, water, plants, and air-emissions	Monitoring of facility grounds and surrounding areas at known shutdown facilities (wide area monitoring to detect clandestine facilities).
Overhead surveillance	Observation of security systems and measures, key infrastructure status, and other indicators of warhead production.
On-site inspections	Environmental sampling. Fissile materials detection (radiation sweeps). Observation of security systems and procedures, and key infrastructure status.
Remote monitoring (fissile material detectors, TV surveillance)	Detection of plutonium/HEU presence inside fissile material and warhead storage facilities, and warhead assembly cells.
Facility declarations	Declarations re facility's functions, location of key infrastructure and production capacities.

each other: infrastructure demolition, portal perimeter continuous monitoring, environmental monitoring, overhead surveillance, on-site inspections, and remote monitoring. Each is discussed in turn below.

Infrastructure Demolition

The most direct way to assure that a former warhead production facility is no longer used to assemble nuclear warheads would be to monitor demolition of specialized production infrastructure such as warhead assembly cells. This, however, might not always be possible if the infrastructure has other potential uses in which case alternative transparency measures would need to be employed.

Portal Perimeter Continuous Monitoring

Portal perimeter continuous monitoring (PPCM) around the target facility, similar to that applied at the missile production plants in the United States and Russia under the Intermediate-Range Nuclear Forces (INF) Treaty, is another possible approach. Such monitoring could be designed to channel all incoming and outgoing shipments through a small number of entry/exit points and to monitor all cargo by using radiation detection equipment. The monitoring system could be designed to detect the presence of plutonium, a strong emitter of gamma-radiation.[7]

The use of PPCM techniques, however, could be problematic because of cost and intrusiveness. The very large size and multizone configuration of some warhead assembly facilities in the United States and Russia could also make PPCM impractical.

Finally, because of small size and weight of nuclear warheads (relative to the huge and massive missile containers that were verification targets under the INF PPCM arrangements) portal monitoring systems could be entirely bypassed and nuclear warheads could be smuggled in and out of the facility via a tunnel or by other means.

Environmental Monitoring

Environmental monitoring is a powerful detection technique that is already being adopted by the International Atomic Energy Agency (IAEA) as a part of its Integrated Safeguards Program to detect clandestine fissile material production facilities and operations. In the context of a known former nuclear warhead assembly facility, environmental monitoring could be conducted by inspectors during site visits or continuously by automated monitoring stations.[8]

In either mode, environmental monitoring would begin with an analysis of environmental signatures associated with warhead production operations. Possible effluents could include[9]:

- fissile and other nuclear materials such as plutonium, uranium (HEU and depleted uranium), tritium, or isotopes used in the production of radioisotopic thermoelectric generators (RTGs);
- high-explosive materials; and
- warhead-specific materials, such as beryllium, gold, and other specialty metals, certain organic materials (solvents, etc.), specialty plastics, and others.

A facility-specific pathway analysis would then be required to determine optimal monitoring points and collection/analysis techniques. Potentially useable could be surface swipes inside critical productions areas, and sampling of soil, plant life, water, waste streams (filters, laundry waste, and others), and gas and particulate effluents on the facility's grounds or in its immediate vicinity. These samples then could be analyzed by mass-spectrometry or other techniques. An additional technology development effort would likely be required to make equipment portable, and to optimize existing tools for real-time sample collection and analysis in the field (preferably).

A critical element of environmental monitoring at a former (as opposed to clandestine) warhead assembly facility would be to establish baseline levels of contamination associated with the past production. This baselining effort could include a set of initial measurements and a careful analysis of a facility's records of its emissions and waste generation associated with production operations in the past. A comparison of a facility's environmental signature relative to its baseline values could enable the inspectors to determine the facility's status and, if operations resumed, their type and workload.

The utility of environmental monitoring at a known former warhead assembly plant could be limited in some cases, however. First, at least in the United States and Russia, warhead assembly facilities work with sealed plutonium pits and HEU components. Detection of fissile materials in this case (after fissile component production) is not possible in the absence of their accidental release. Second, the use of high-efficiency filters could possibly reduce effluents to the point where they would not be detectable against the background contamination. Third, environmental sampling inside the facility would likely be unacceptable because it could reveal sensitive design information (for example, information about materials used to manufacture nonnuclear components of nuclear explosive packages) from past production activities. Finally, some facilities (for example, Avangard, as discussed below) would continue using high-explosives and, possibly, depleted uranium in manufacturing conventional weapons, even after they have phased out warhead assembly/disassembly operations. Environmental monitoring techniques then could be defeated by masking emissions from nuclear weapons operations by those from permitted production activities. Background levels of contamination also could be increased artificially by dispersing contaminants at likely monitoring points prior to initial baselining.

Overhead Surveillance

Overhead surveillance would be among the primary monitoring tools for nuclear weapons production facilities. The United States and Russia each have deployed and operated high-resolution (possibly 10 cm) photographic reconnaissance satellites. Both countries have also signed the Open Skies treaty that provides for aircraft overflights of the territory of its signatories. Open Skies imagery is expected to have a resolution of approximately 30 cm. Relatively high-resolution satellite imagery is also now available commercially.[10]

The United States and Russia have already collected extensive imagery data on nuclear weapons facilities on each other's territories and in other countries. Each country also has sophisticated imagery analysis capabilities that allow for advanced assessments of imagery data. Monitoring of a shutdown nuclear weapons facility then would involve periodic collection of imagery and its evaluation against the existing baseline data. A very significant advantage of overhead surveillance would be its nonintrusive nature.

On-Site Inspections

On-site inspections have been a critical verification technique under the INF and START treaties. In the nuclear area, site visits are also a standard element of IAEA safeguards and monitoring arrangements for U.S.-Russian bilateral efforts to control management and disposition of excess stocks of nuclear materials, such as the downblending of HEU from weapons under the 1993 U.S.-Russian HEU agreement. (No U.S. nationals, however, have ever visited active nuclear weapons assembly/disassembly facilities in Russia and vice versa.)

Any on-site inspection regime at a warhead production facility would presumably begin with a base-line (familiarization) visit to confirm facility declarations. Subsequent inspections could be periodic and/or short-notice. Inspectors could be expected to use visual observation, radiation detection equipment, and tags and seals. Managed-access inspections (involving choreographed escorted tours, shrouding of sensitive equipment, etc.) would be used for facilities involved in conventional munitions work or other sensitive activities.

Remote Monitoring

Remote monitoring has become an important cost-effective way to reduce the frequency of on-site inspections. It is used extensively by the IAEA to monitor plutonium storage and processing operations in Japan. Remote monitoring is applied domestically at U.S. nuclear facilities to reduce the frequency of nuclear materials physical inventories and personnel exposure to radiation. U.S. and Russian technical experts are also investigating potential applications of remote monitoring technologies to arms control and transparency scenarios.

MONITORING OF AVANGARD-TYPE FACILITIES

The foregoing overview of the six monitoring approaches suggests that the utility of infrastructure demolition, PPCM, and environmental monitoring is probably limited to a narrow class of small, inactive sites. Overhead surveillance, on-site inspection visits, and remote monitoring would likely be the primary instruments for monitoring known former warhead assembly facilities that continue significant industrial and national security activities.

The examples of such facilities include the Avangard plant in Sarov, Russia, and the former Burlington AEC (Atomic Energy Commission) plant near Burlington, IA, in the United States. The Avangard plant, after its projected closure as a weapon assembly plant in 2003, will be involved in limited nuclear weapons work (manufacturing of certain warhead components and subassemblies, such as advanced permissive action links or PAL devices, and support equipment), production of advanced conventional weapons, and various civilian projects. The Burlington AEC plant occupied the Line 1 technical area of the today's Iowa Army Ammunition Plant (IAAP) and produced nuclear weapons from 1949 to 1975, before all warhead assembly operations were consolidated at Pantex.[11] At present, IAAP's Line 1 manufactures advanced conventional weapons including shaped charges, and warheads for antitank (TOW, Hellfire, and Javelin) and air-defense (Patriot, Stinger, etc.) missiles.[12]

Monitoring of Avangard-type facilities presents a number of challenges. The production of advanced conventional munitions or nuclear weapon components utilizes skills, equipment, and infrastructure that were used in the production of nuclear weapons and, thus, is associated with many of the same indicators. For example, according to Yuri Zavalishin, Avangard's former director, the high effectiveness of the Ataka antitank missile, which is produced by Avangard, is due to the "use of materials, engineering techniques, and technologies that are used in nuclear weapons manufacturing."[13] In particular, the Avangard plant will maintain its HE activities and infrastructure. Similarly, much of the former nuclear warhead production infrastructure at the Burlington plant is currently used for explosives loading operations. Also, because of the sensitive nature of conventional weapons production, access to Avangard or Burlington will remain limited. For example, in the case of the Burlington facility, as of 1983, "[p]rocesses and equipment in these [Line 1] areas . . . were either classified or highly sensitive."[14] Access limitations would make monitoring arrangements more difficult.

Radiation detection of fissile materials during short-notice, managed-access inspections of critical production and support areas or during continuous remote monitoring of former warhead assembly bays and cells, and overhead observation of facility's security posture could be useful in addressing the above difficulties and are promising monitoring techniques.

Short-Notice Inspections of Critical Production and Support Areas

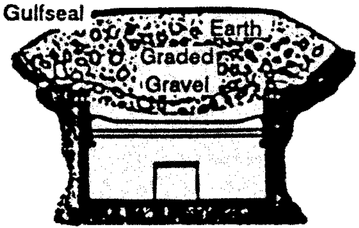
U.S. and Russian nuclear warhead production facilities contain specialized fissile material and warhead infrastructures, including storage buildings for fissile material components and subassemblies, storage facilities for intact warheads, and warhead assembly cells and bays. Under an ideal transparency scenario, these critical infrastructure buildings would be listed in facility's initial declarations and would be made open for on-site inspections.

Short-notice inspections, similar to those conducted under the INF treaty, could be particularly effective.[15] In conducting a short-notice inspection at a former warhead assembly plant, inspectors would select critical work and storage areas; the host party would have a limited amount of time (possibly a few hours) to stop production operations and shroud sensitive equipment (for example, if target rooms/buildings are used for loading conventional munitions). This waiting period, however, should be made short enough as to preclude the host from evacuating and concealing nuclear weapons and components. Inspectors would conduct radiation sweeps of target areas to confirm that no nuclear materials or weapons are present. Similar measures involving the use of radiation (neutron) detection equipment have already been negotiated by the United States and Russia in the START I treaty to confirm that no nuclear-armed cruise missiles are present at bomber bases that have been declared nonnuclear. Radiation measurement-based managed inspections and shrouding/masking of production equipment would provide for adequate protection of sensitive conventional weapons operations.[16]

Remote Monitoring of Assembly Bays and Cells

The operations of assembly and disassembly of fission primaries involve handling of plutonium-containing pits and uncased HE components together and are particularly dangerous because of the risk of plutonium dispersal in an HE accident. To reduce this risk, operations on warhead primaries are carried out inside specialized structures that are designed to contain or vent an explosion and prevent a release of radioactivity (see Figure 1 and Appendix: *U.S. Warhead Assembly Cells and Bays and Russian "Towers"*).

Continuous unattended remote monitoring, involving a radiation detector system placed directly inside former warhead assembly cells and bays, could be a promising approach and would not compromise sensitive information about conventional weapons manufacturing. A large and efficient plastic detector can detect a 2-kg shell of plutonium in a several millimeter thick steel container at a distance of approximately 12 m.[17] (A similar shell of HEU would be detectable at approximately 3 m.) This detection range would be sufficient to detect the operation of assembly of a warhead primary (which involves handling of an unshielded plutonium pit) inside a 10-m diameter Gravel Gertie's round room. More than one detector could be installed in rooms of a larger size. A detector system would have to operate unattended, have a uninterruptible power supply, and be self-monitored by a TV camera or by other means to detect tampering and to assure that detectors are not shielded from their target areas.[18] (A 1.5 cm thick lead shield would reduce the detection rate for a 2-kg plutonium shell to



Cross Section of Gravel Gertie

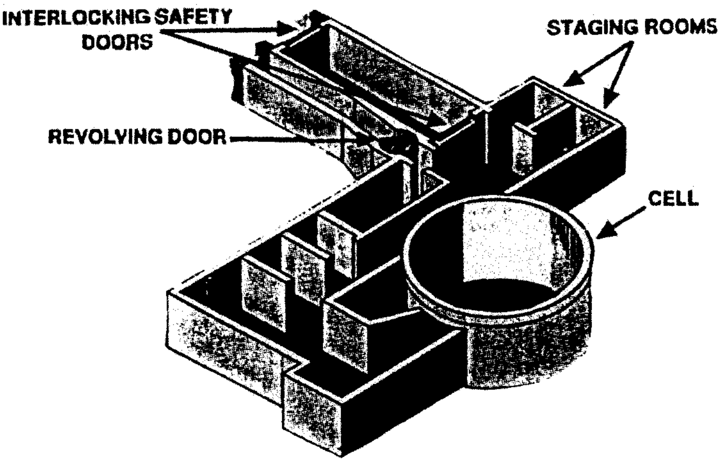


Figure 1: Gravel Gertie assembly cell (from George West *United States Nuclear Warhead Assembly Facilities (1945–1990)*, March 1991, Pantex, Amarillo, TX).

approximately 4 m.) In addition to area monitoring, portal monitors could be installed at shipping docks, transport passageways, or entryways to critical areas and buildings.

Observation of Facility's Security Posture

Nuclear weapons production facilities maintain very high levels of security. Observable security indicators include:

- a multifence security perimeter with well-maintained isolation zones, guard towers, intrusion-detection sensors, and security lighting systems;
- access control measures (security checkpoints); and
- protective force and special response elements (required, for example, to recover stolen nuclear weapons or materials).

High-level security systems and procedures, typical of nuclear weapons facilities, are expensive to develop, implement, and maintain. They are unlikely to be employed unless a facility is engaged in highly sensitive activities or uses high-value equipment and materials. For example, to reduce security-related expenditures, the Russian government is expected to cancel the closed-city status of Zarechny, one of Russia's 10 closed nuclear cities, after the planned phase-out of warhead dismantlement work at the START production complex.[19]

Aerial photographs, provided by the U.S. Geological Survey and available on the Internet, of the former Burlington AEC plant (Burlington, IA) and the Pantex plant (Amarillo, TX) also demonstrate the point (see Figures 2 and 3).[20]

The security posture of the IAAP's Line 1 (former Burlington AEC plant) corresponds to that of conventional military and industrial installations. The 1994 overhead imagery indicates a simple, single-fence perimeter around the Line 1 area (which is located within a larger restricted zone of the IAAP plant). There is no isolation zone or perimeter intrusion and assessment system (PIDAS) bed visible around the area. Instead, fragments of a former inner security perimeter (presumed currently inactive) around one of Line 1's two former Gravel Gertie and mechanical assembly bays complexes can be discerned on the imagery.

In contrast, Pantex, currently the only operating warhead production facility in the United States, maintains a very high security posture. The imagery of one of its technical areas reveals a well-maintained security perimeter, which includes three fences, an isolation zone, security lighting systems, CCTV towers, and intrusion detection sensors.[21] Also visible are the security checkpoint and several (presumably, protective force) vehicles parked by what could be a central alarm and response force station.

It should be noted that "before and after" security differences at Avangard could be not as significant as those between the Pantex plant and the former Burlington AEC Plant because the current level of Avangard security is presumably lower than that at Pantex.

MONITORING APPROACHES AND STRATEGIC OBJECTIVES OF A TRANSPARENCY REGIME

The choice of monitoring techniques and the scope of monitoring would depend on political and strategic objectives of a transparency regime. For example, contraction of Avangard's perimeter and the use of outside buildings for civilian

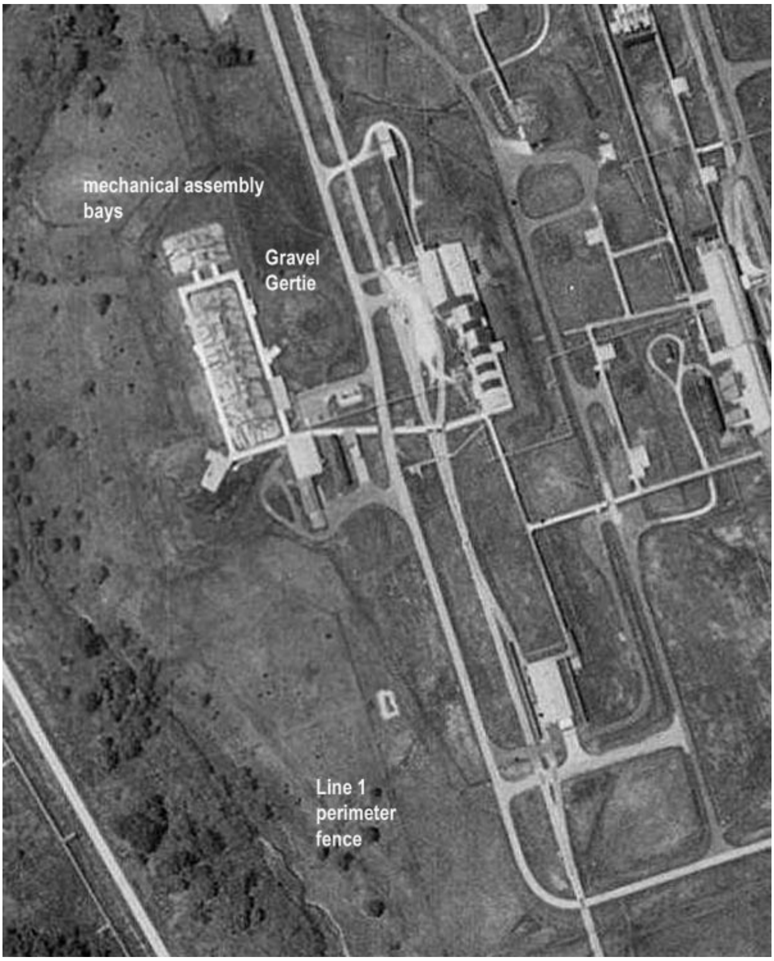


Figure 2: Line 1 of the Iowa Army Ammunition Plant (Burlington, IA); USGS aerial photography 17 May 1994.

purposes would reduce Russia's overall warhead manufacturing capacity and could be easily confirmed by routine satellite surveillance and on-site and town visits by representatives of foreign governments and commercial companies. No special monitoring measures would be required to confirm such capacity reductions.

The absence of warhead assembly/disassembly operations could be ascertained by implementing the monitoring approaches described in this article. The presence of U.S. representatives in the open parts of Avangard and in Sarov

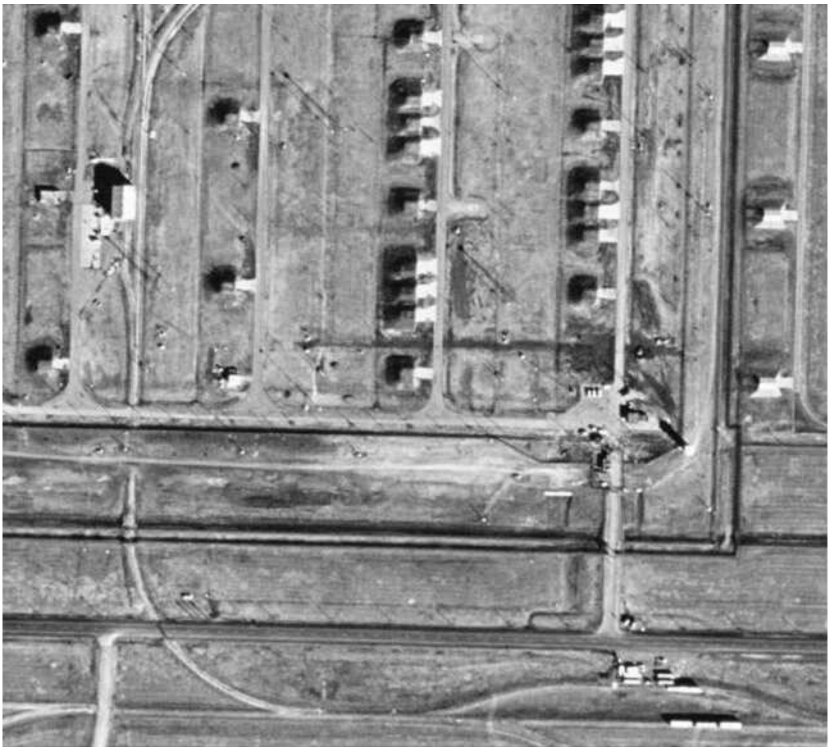


Figure 3: Zone 4 of the Pantex plant (Amarillo, TX); USGS aerial photography, 22 February 1997.

would also provide for reasonable assurances that the facility is not engaged in prohibited activities.

A complete elimination of Avangard's standby (mobilization) production capacity, which could significantly contribute to a hypothetical surge production effort, would be a more difficult goal to achieve.[22] Indeed, because of its colocation with the Institute of Experimental Physics (VNIIEF), Russia's primary warhead R&D center, the continuing manufacturing of warhead components, and the production of conventional weapons, Avangard would maintain or have a ready access to much of the infrastructure, equipment, and personnel required for warhead assembly operations. Achieving a high level of confidence that no surge production capability remains at Avangard could require demolition of its warhead assembly cells and other key infrastructure.

It also should be noted that capacity reductions or even irreversible closure of the Avangard plant (and START in Zarechny) would be of limited strategic benefit if warhead production continues unrestricted at Russia's remaining large warhead assembly complexes in Lesnoy (Sverdlovsk-45) and Trekhgorny (Zlatoust-36). A monitored shutdown of Avangard and START therefore would need be a first step in a step-by-step approach leading to limits on new warhead production at the remaining serial facilities in the United States and Russia.

CONCLUSION

The capability to monitor the cessation of nuclear warhead assembly/ disassembly operations could be highly desirable for several reasons. First, verification that certain identified facilities were no longer capable of nuclear warhead production would reduce concerns regarding capability for break-out or rapid production of new warheads. Such capability could increase confidence that Russia was not maintaining a warhead production infrastructure inconsistent with a greatly reduced nuclear arsenal. Second, because Russia's excess warhead production capability remains a strategic concern to the United States, confidence in the reduction of this capability could increase domestic U.S. support for cooperative nuclear security programs with Russia and help improve the overall bilateral relationship. Finally, methods and technologies that can effectively monitor nonproduction of nuclear warheads could eventually be very valuable to easing nuclear tensions between other states.

A monitoring regime to confirm a shutdown or converted status of a known former warhead assembly plant could include facility declarations, overhead surveillance, on-site inspections and remote monitoring. Transparency measures would be designed to detect fissile materials, as well as monitor the facility for other indicators associated with serial production of nuclear weapons.

Despite these potential advantages, verification of nonproduction of nuclear weapons is inherently challenging because of the low-signature of warhead operations and the potential use of production facilities for alternative purposes. For example, monitoring of Avangard could be difficult because of its planned continued production of nuclear warhead components, production of conventional munitions, and proximity to the warhead design institute VNIIEF. Nevertheless, transfer of excess buildings and personnel outside of the security perimeter and application of the proposed monitoring approaches could provide an adequate assurance that Avangard no longer produces nuclear weapons. Achieving high confidence that a shutdown facility does not retain a significant standby capacity could require the elimination of critical elements of the facility's infrastructure. Limits on new warhead production at the remaining assembly plants would greatly increase the strategic value of such monitoring.

NOTES AND REFERENCES

1. Other activities that are critical to the nuclear warhead production cycle but not considered in this analysis include production and processing of tritium, fabrication of fissile material components, warhead R&D and surveillance, and fabrication of specialized nonnuclear components.

2. The NEP assembly operation involves mating or bonding of main charge high-explosive (HE) components to a nuclear pit to produce a fission primary subassembly, and emplacement of the primary, thermonuclear secondary (for thermonuclear warheads), and additional non-nuclear components inside the NEP casing. During the final mechanical assembly, the NEP and other electronic and mechanical components (a fusing and firing system, tritium gas transfer system, neutron generator and others) are placed inside a warhead (bomb) casing and integrated into a functional package. This description of assembly/disassembly operations is based on "1998 Programmatic Information Documents For Pantex Plant," (Batelle Pantex/Mason & Hanger Corporation, 1998). It should be noted that the description is highly notional; actual operations for a particular type of warhead would depend on its specific design features.

3. See, for example, Yuri Zavalishin, *Object 551* (Saransk: Krasny Oktyabr, 1996), 185–205.

4. For a discussion of warhead production indicators see Oleg Bukharin and James Doyle, "Verification of the Shutdown or Converted Status of Excess Warhead Production Capacity: Technology Options and Policy Issues" (Los Alamos National Laboratory, report LA-UR-01-5000, 2001).

5. The task of monitoring and analysis of operations-related signatures could be considerably more difficult for modern small-to-moderate sized underground facilities such as the Device Assembly Facility at the Nevada Test Site in the United States.

6. Detection of an undeclared facility would probably require wide-area environmental monitoring, overhead surveillance, and challenge inspections that are supported by all-source national intelligence.

7. Modern portal monitors to control vehicular traffic are capable of detecting tens of grams of plutonium and hundreds of grams of HEU. For example, Russian-made monitors that include gamma-ray and neutron detectors, are capable of detecting 60 g of plutonium encased in a 4-cm thick lead container. (See: "Lab-to-Lab Cooperation: Portal Monitors as a First Line of Defense," *Arms Control and Nonproliferation Technologies* (First/Second Quarters 1996), 16–17.) They would therefore easily detect warhead components containing kilogram-quantities of nuclear materials if no heavy shielding is applied.

8. For a discussion of possible application of environmental monitoring techniques to nuclear weapons facilities see *Confidence, Security & Verification* (Aldermaston, United Kingdom: Atomic Weapons Establishment, 2000), 30–37.

9. See, for example, A. Hamilton, D. Swindle, D. Manning, “Development and Applications for the International Safeguards Environmental Measurements (ISEM) Database,” (paper presented at the Annual Meeting of the Institute of Nuclear Materials Management, Naples, FL, July 1994), 1190–1202.

10. High-resolution commercial imagery is generated by the Ikonos satellite and is marketed by Space Imaging (<http://www.spaceimaging.com>). The resolution of current Ikonos imagery is 1 m; the next generation of commercial imagery is expected to have a resolution of 50 cm.

11. Ann Arnold Lemert, *First You Take a Pick & Shovel: The Story of Mason Companies* (Lexington, KY: The John Bradford Press, 1979), 160–189.

12. “Iowa Army Ammunition Plant: Installation Action Plan 2000” (U.S. Army Operations Support Command Environmental Team, March 2000), 2; George Davis, “Cleaning Up the Iowa Army Ammunition Plant A Partnering Success Story,” (Omaha, 11 March 1998 <http://www.nwd.usace.army.mil/pm/partner.98/HOWE/tsld001.htm>).

13. Yuri Zavalishin, *“Avangard” Atomic* (Saransk: Krasny Oktyabr, 1999), 214.

14. “Iowa Army Ammunition Plant: Written Historical and Descriptive Data” (Historical American Engineering Record, HAER No. IA-13, 1984), 74; (see: <http://memory.loc.gov/ammem>).

15. Short-notice inspections under the INF treaty were conducted to verify inventories of treaty-limited missiles. Each party had a right to conduct 20 inspections per year during the first three years; 15 inspections per year during the subsequent five years; and 10 inspections per year during the last 10 years. A standard protocol involved the following: arrival to one of country’s point of entry; selection by inspectors of inspection location; transportation of inspectors by the host country to the inspection site within nine hours; and an escorted walk-through of the site. An inspection was to be completed within 24 hours.

16. Additional analysis would be required to determine if direct-access, short-notice visits and the use of electrical equipment would jeopardize safety of HE loading or other hazardous production operations.

17. W. Murray, R. Morgado, C. Frankle, “Final Report: Scoping Study of SNM Detection and Identification for Adjunct On-Site Treaty Monitoring” (Los Alamos National Laboratory, report LA-12990, UC-000, July 1995), 16. Plastic scintillation detectors detect both neutron and gamma radiation but do not discriminate energy.

18. The Radiation Identification System developed in the Sandia National Laboratories, for example, is capable of continuous monitoring of radiation (gamma and neutron) levels without operator’s intervention for an extended period of time. “Radiation Identification System,” *Arms Control and Nonproliferation Technologies* (First/Second Quarters 1996), 28.

19. See, for example, “On the Agenda: the Problem of Employment,” *Atompressa* (46, December 2000), 3; and Ludmila Saratova, “How do You Live, the Weapons Plant, *Gorodskoy Kuryer* (January 23, 1999), 3.

20. For information about aerial surveillance imagery see USGS TerraServer web site (<http://mapping.usgs.gov/digitalbackyard/doqbkyd.html>). Imagery can be

downloaded from the Microsoft TerraServer Web Site (<http://terraserver.homeadvisor.msn.com/default.asp>).

21. The picture features Zone 4, Pantex's storage area for intact nuclear weapons and plutonium pits.

22. It is not clear whether there is a realistic scenario under which Russia would restart Avangard. The production would most certainly first increase at the Trekhgorny and Lesnoy facilities. Potentially, Avangard could be tasked to produce warheads of certain types that were not produced by the operating facilities (for example, warheads for medium- and short-range ballistic missiles). This, however, would make sense only if Russia had an adequate stockpile of such delivery systems.

23. George West, *United States Nuclear Warhead Assembly Facilities (1945–1990)* (Amarillo, TX: Pantex 1991).

24. "Avangard—Half-Century Old," *Atompressa* (8, March 1999), 3.

APPENDIX—U.S. Warhead Assembly Cells and Bays and Russian "Towers"

At Pantex in the United States, warhead primaries and nuclear explosive packages are assembled and disassembled inside Gravel Gertie assembly cells although operations on primaries containing insensitive explosives are also carried out in blast-proof assembly/disassembly bays. Gravel Gertie assembly cells were designed in the 1950s and were subsequently constructed at every U.S. warhead assembly/disassembly facility handling HE and fissile materials together. Gravel Gertie assembly cells are designed to vent explosion gases and filter radioactive dust after an HE explosion. In a typical cell, the "round room," where assembly/disassembly operations take place, is a reinforced concrete tube 10.4 m in diameter and 6.6 m high. The cell has a labyrinth entrance with separate pathways for personnel and equipment, and a screen-filter roof covered with approximately 6 m of gravel.[23]

Mechanical assembly bays at Pantex are used for final mechanical assembly and disassembly of intact warheads and nuclear explosive packages containing insensitive HE. Warhead radiography facilities, which are used to check the position of warhead switches and observe its other internal components, are also located in mechanical bays. A typical assembly/disassembly bay is rectangular room with reinforced-concrete walls that are 0.5–1.4 m thick and concrete-slab roof with a 0.6 m thick earth overburden. Access to assembly bays is through interlocking blast doors.

Russian facilities also reportedly use specialized blast-proof assembly cells. An assembly cell of presumably a newer design (such cells are also called "towers") at the Avangard plant was described as follows:[24] "This is a reinforced concrete cell the internal diameter and the height of which are approximately 10 m. Adjacent to the tower are airlock rooms, corridors to transport ‘objects,’ ventilation filter and vacuum pump rooms, and so on. The tower and airlocks have over 1.5-m thick walls. Other premises have walls that are over 0.5 m thick. The premises are separated by 150-mm thick armored doors. To provide for a hermetic isolation of the tower, there is another door between the airlock and the corridor.”