# Future Directions in Nuclear Arms Control and Verification

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Delivered at the
62nd Meeting of the
German Physical Society
Regensburg, Germany
26 March 1998

**Abstract**

To date, nuclear arms control has focused on restricting the number and capabilities of strategic nuclear delivery vehicles—intercontinental missiles and bombers. In the future, it will become increasingly important to combine these measures with restrictions on nuclear warhead and fissile-material stockpiles and on the operation and targeting of nuclear forces. Restrictions on nuclear warheads, materials, operations, and targeting would not only help improve stability, but would also help reduce the risk of accidental, unauthorized, or erroneous use of nuclear weapons. A major challenge is verifying compliance with such restrictions. This paper outlines the technical possibilities for verifying limits on stockpiles of warheads and fissile materials, on the dismantling of nuclear warheads and the disposition of fissile materials, and on the launch-readiness of nuclear forces in the hope of stimulating further research on these topics.

## Introduction

The last decade has seen great progress in nuclear arms control between the United States and the former Soviet Union. The INF Treaty eliminated all ground-launched weapons with ranges between 500 and 5,500 kilometers. The START I Treaty cut in half the number of strategic warheads deployed by the superpowers, from nearly 25,000 in 1989 to about 13,000 in 1998.[1] The START II Treaty, which has not yet been ratified by Russia, promises to cut these arsenals in half again, to a combined total of less than 7,000 deployed strategic warheads. In addition, both countries have agreed to reduce the number of nonstrategic nuclear weapons, although these commitments are informal and not subject to verification.

These reductions, while certainly welcome, are not enough. The risks posed by nuclear weapons would remain unacceptably high even after the full implementation of START II. These risks are of several types. First, there is the risk that leaders of the nuclear weapon states might intentionally use or threaten to use nuclear weapons in a crisis. Second, there is the risk of accidental, unauthorized, or erroneous use of such weapons. Third, there is the risk that the current arms control regime could break down, freezing arsenals at high levels or triggering a renewed arms race. Fourth, there is the risk that additional countries might acquire nuclear weapons, either through theft or diversion or as a result of a more general weakening of the nonproliferation regime.

Faced with these risks, and in the absence of hostility between the nuclear powers, some former civilian and military leaders have called for a general prohibition on nuclear weapons.[2] As a practical matter, this is premature. Prohibition will not be possible until relations among the major powers—in particular, Russia, China, and the major NATO countries—are more like current relations among the United States, the United Kingdom, and France.[3]

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[1] Robert S. Norris and Thomas B. Cochran, US–USSR/Russian Strategic Offensive Nuclear Forces: 1945–1996 (Washington, DC: Natural Resources Defense Council, January 1997); Robert S. Norris and William M. Arkin, "Nuclear Notebook," ***Bulletin of the Atomic Scientists***, Vol. 54, No. 1 (January/February 1998), p. 71; Robert S. Norris and William M. Arkin, "Nuclear Notebook," ***Bulletin of the Atomic Scientists***, Vol. 54, No. 2 (March/April 1998), p. 71.

[2] See, for example, Craig Cerniello, "Retired Generals Re-ignite Debate Over Abolition of Nuclear Weapons," ***Arms Control Today***, Vol. 26, No. 9 (November/December 1996), p. 14-15, 18.

[3] For a more detailed discussion, see National Academy of Sciences, Committee on International Security and Arms Control, ***The Future of U.S. Nuclear Weapons Policy*** (Washington, DC: National Academy Press, 1997), http://www.nap.edu/readingroom/books/fun; and Steve Fetter, "Verifying Nuclear Disarmament" (Washington, DC: Henry L. Stimson Center, Occasional Paper No. 29, October 1996), http://www.stimson.org/pdf/fetter.pdf.

In the meantime, we can reduce the risks posed by nuclear weapons through properly designed and implemented arms control measures, and simultaneously prepare the foundation for much deeper reductions in the number of weapons, perhaps all the way down to zero. These measures should include:

- verified reductions in the total number of nuclear warheads, including nondeployed and nonstrategic warheads, and in stockpiles of weapon-usable fissile materials;
- reductions in the readiness of nuclear forces, and corresponding increases in the warning time of an attack;
- a shift away from counterforce strategies and targeting doctrines; and
- a robust firebreak between theater and strategic-capable missile defense systems.

Each of these arms control measures raises new verification challenges, which are reviewed below.

## Reductions in Warheads

To date, nuclear arms control has focused on restricting the number and capabilities of strategic nuclear delivery vehicles—intercontinental missiles and bombers. The number of nuclear warheads mounted on deployed strategic delivery vehicles is subject to verification under START II, but the numbers of nonstrategic or nondeployed warheads are not limited by any agreement. Although limits on delivery vehicles and launchers will remain of central importance, it will be increasingly important to complement these with controls on all nuclear warheads.

This is recognized is the March 1997 Joint Statement of Presidents Clinton and Yeltsin issued in Helsinki, which calls for a START-III agreement that includes "measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads…to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads." The Presidents also agreed to "explore, as separate issues, possible measures relating to…tactical nuclear systems, to include appropriate confidence-building and transparency measures," and to "consider the issues related to transparency in nuclear materials."

Agreed limits on nuclear-warhead and fissile-material stockpiles, together with associated transparency and verification measures, would have several benefits:

- First, they would build confidence in each side's understanding of the size of the other's stockpiles of nuclear weapons and fissile materials, and the rate of reduction in these stockpiles.

- Second, they would build confidence that the nuclear arms reductions being carried out are irreversible, and that the potential for rapid and large-scale breakout from agreed limitations is very low.

- Third, they would build confidence that nuclear weapons and fissile materials are secure from theft or unauthorized use, and provide information needed to strengthen mutual cooperation toward that end.

- Finally, such measures would build political support for ratifying and implementing the START agreements, would lay the foundation for deeper reductions in nuclear arsenals; and would strengthen the nonproliferation regime by demonstrating a commitment to further nuclear arms reductions.

A comprehensive transparency regime would have several components, including initial declarations and exchanges of information, baseline inspections to gain confidence in the accuracy and completeness of the declarations, and inspections to verify the dismantling of warheads and the ultimate disposition of warhead components.

**Declarations**. We should begin with a comprehensive declaration or exchange of data on the location, status, type, and serial number of every nuclear device that exists.[4] The location of a warhead would be a particular storage bunker or delivery vehicle. The status would indicate whether the warhead is in the active or reserve inventory or whether it is slated for dismantling and, if so, when. If steps had been taken to render the warhead unusable, such as removing tritium, batteries, or other components, this could be indicated as well. The serial number could serve as a tag for the warhead, or special tags could be developed and applied for this purpose. The declaration would be updated at agreed intervals—every six months or so.

Declarations would be valuable even without transparency measures. Early declarations would build confidence and would stimulate both governments to ensure that their accountancy systems are accurate and understandable. In the case

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[4] In June 1995, the United States proposed a modest stockpile data exchange agreement, which called for exchanging data, on a confidential basis, on total current inventories of nuclear weapons and fissile materials, as well as the total number of nuclear weapons dismantled each year since 1980, and the type and amount of fissile material produced each year since 1970. Unfortunately, Russia rejected the proposal as "too comprehensive."

of historical information, such as the rates of production of nuclear weapons or fissile materials, it is important to assemble this information today, while the personnel who were involved and in charge of these operations are still available.

**Baseline inspections**. But the real value in declarations would come with their verification, and the second element of a transparency regime would be baseline inspections to verify the accuracy of the declaration. Since deployed strategic warheads are covered by START and all tactical warheads are in storage, the baseline inspections would mostly involve verifying the number of nonstrategic and nondeployed warheads in storage bunkers.

Inspectors could visit a particular bunker on short notice and verify that the declared number of warheads is present—no more, no less. Alternatively, inspectors could randomly select a small number of warheads for inspection and verify that the serial numbers on the warheads matched those listed in the declaration. Sampling can greatly reduce the number of warheads that are examined. For example, if a random sample of 20 or 30 warheads turned up no undeclared warheads, then one could be highly confident that significant numbers of undeclared warheads do not exist at that site.[5]

There are, however, two key problems in verifying a warhead declaration. The first is knowing that an object which is declared to be a warhead of a particular type really is a warhead of that type. This could be dealt with by developing "fingerprints" or templates of warhead types, and using random sampling to verify that a particular warhead is an authentic warhead of the declared type. For example, Russia could present one or more SS-18 warheads for fingerprinting, or warheads could be selected from a deployed missile by U.S. inspectors. A set of agreed characteristics could be measured: length and diameter; mass; the relative strength of neutron emissions or gamma-ray emissions; or heat output. A signature of this type could be extremely difficult to spoof.[6] If such measurements would

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[5] Let f be the fraction of warheads at the site that are undeclared, n be the number of warheads sampled, and P be the probability that at least one of the sampled warhead is undeclared (i.e., a violation is detected). If the total number of warheads at the site is much larger than n, then $P = 1 – (1– f)^n$. If f = 0.1and n = 30, then $P = (1 – 0.9^{30}) = 0.96$. In other words, if 10 percent of the warheads at a site are undeclared, then it is highly likely (about nineteen chances in twenty) that a random sample of 30 warheads would contain an undeclared warhead.

If the total number of warheads at the site is not much larger than the number sampled, the probability of detecting a violation is much higher. Let N be the total number of warheads from which the sample of n is drawn, and M = fN be the total number of undeclared warheads; then $P = 1 – (N–M)!(N–n)!/(N–M–n)!N!$. For example, if N = 100 and f and n are as above (0.1 and 30, respectively), then $P = 1 – 90!70!/60!100! = 0.977$.

[6] To appreciate the detail and complexity of a high-resolution gamma-ray signature, see Steve Fetter, Thomas B. Cochran, Lee Grodzins, Harvey Lynch, and Martin S. Zucker, "Gamma-ray Measurements of a Soviet Cruise-Missile Warhead," ***Science,*** Vol. 248 (18 May 1990), pp. 828-834.

reveal sensitive weapon-design information, an automated system could be devised to give a simple "yes" or "no" answer to the question, "Is this an SS-18 warhead?"[7]

A second, more severe, problem in verifying declarations is knowing that they are complete. How could the United States and Russia be confident that the other had not hidden a few hundred or even a few thousand warheads? Warheads are so small and inconspicuous that we can never be absolutely sure that there are no hidden warheads. We can, however, substantially reduce uncertainties and, over time, develop confidence in the declaration.

Challenge or anytime-anywhere inspections are often mentioned as one way to detect undeclared warheads, if they exist. This does not seem very promising, however, because a well-designed plan to hide warheads would give few clues about where to look. A better approach would be to exchange historical information on the nuclear stockpiles as part of the initial declaration. For example, we could exchange information on the history of every nuclear device ever manufactured, including the dates and locations of assembly and disassembly and movement between various storage and deployment facilities. In addition, data could be exchanged on the production of fissile materials and warhead components, and on the location, design, and operation of facilities involved in the production of warheads and fissile materials.[8] These records could be examined for internal consistency, for consistency with the stockpile declaration, and for consistency with archived intelligence data.

In some cases, on-site inspections might be able to confirm the accuracy of the declaration. For example, measurements of isotope ratios in the permanent structural components of plutonium-production reactors and in depleted uranium tailings, could be used to verify declarations of plutonium and HEU production.[9]

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[7] The CIVET ("Controlled Intrusiveness Verification Technology") system, developed at Brookhaven National Laboratory, accomplishes this task with a high-resolution gamma-ray detector and a special-purpose computer without permanent memory.

[8] Indigenous production of nuclear warheads involves numerous steps, including: (1) the mining and refining of uranium ore; (2) the fabrication of uranium fuel and targets for plutonium-production reactors; (3) the operation of these reactors; (4) spent-fuel reprocessing, plutonium purification, and storage of high-level wastes; (5) fabrication of plutonium pits; (6) warhead assembly; (7) warhead storage, deployment, and maintenance; (8) warhead dismantling. In principle, data could be collected on these and other steps, and these data could be examined in detail to verify its internal consistency, and its consistency with other information.

[9] Steve Fetter, "Nuclear Archaeology: Verifying Declarations of Fissile-material Production," ***Science and Global Security,*** Vol. 3, Nos. 3-4 (1992); T.W. Wood, D.C. Gerlach, B.D. Reid, and W.C. Morgan, "Feasibility of Isotopic Measurements: Graphite Isotopic Ratio Method (Richland, WA: Pacific Northwest National Laboratory, April 1994), unpublished manuscript.

Using one technique, the total amount of plutonium produced by a graphite reactor can be verified with an accuracy of about 5 percent.[10]

Uncertainties in the completeness of the declaration cannot be eliminated, but current uncertainties could be reduced substantially. Unclassified U.S. government estimates of the number of warheads in the Russian stockpile are said to uncertain by plus or minus 5,000 warheads, and former Minister of Atomic Energy Mikhailov has been quoted as giving widely divergent estimates for the size of Russian warhead and fissile-material stockpiles.[11] Unless these uncertainties are reduced through a program of declarations and transparency measures, it may be difficult to sustain a cooperative program to reduce the risks posed by nuclear weapons.

**Dismantling**. If we can establish a baseline inventory of nuclear warheads, we can proceed to verifiably dismantle them. There are three main methods for verifying the dismantling of warheads.[12] The first is to verify that a nuclear warhead had been removed from the stockpile, and that the corresponding nuclear components—in particular, the plutonium pit—had been placed in a monitored storage facility. For example, Russia could verify that a U.S. warhead had been removed from the storage area at Pantex, and that some days later a pit had been placed in the storage area. The "fingerprinting" procedures mentioned earlier could be used to assure that the object to be dismantled was an authentic warhead of a given type, and that the object which is subsequently placed in storage was an authentic pit. It may be possible to verify that the pit was taken from a certain type of warhead (by comparing the radiation signatures of the warhead and pit), or from a particular warhead (by irradiating the warhead with a burst of neutrons and measuring the fission-product gamma-ray signature of the pit some days later). Again, sampling could be used to minimize the number of warheads or pits that would be subjected to detailed examination.

A second method would be perimeter-portal monitoring at the dismantling facility. The portal would be equipped with a system to detect and verify the

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[10] B.D. Reid, Dave Gerlach, Pat Heasler, Jim Livingston, "Trawsfynydd Plutonium Estimate" (Richland, WA: Pacific Northwest National Laboratory, September 1997), p. 100. Five percent refers to one standard error.

[11] In 1992, the CIA estimated that Russia had 30,000 nuclear weapons, "plus or minus 5,000." (See "Testimony of Lawrence Gershwin before the House Defense Appropriations Subcommittee," 6 May 1992.) Subsequent statements by Russian Minister of Atomic Energy Victor Mikhailov that the Russian stockpile peaked at 45,000 warheads cast doubt on the CIA estimate, and emphasized further the difficulty of estimating warhead stockpiles with national intelligence alone.

[12] These are reviewed in Department of Energy, Office of Arms Control and Nonproliferation, ***Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement*** (Washington, DC: U.S. Department of Energy, 19 May 1997).

authenticity of warheads entering the facility, and to detect fissile materials exiting the facility. Components containing plutonium or uranium would be stored pending their ultimate disposition under mutual monitoring; other components could be destroyed or recycled, as agreed by the parties.[13]

A third method would track the warhead and its components through the dismantling process. Although this is often considered to be excessively intrusive, it may be possible to protect sensitive information. The monitoring party could, for example, track the movement of warhead up to the disassembly cell, track the movement of the fissile components from the disassembly cell to the storage area, and verify that the disassembly cell contained no warheads or warhead components both before and after the disassembly procedure. Monitoring could be done by on-site inspectors, or remotely using secure video links or radio beacons.

**Disposition**. The final component of a warhead transparency regime would be the disposition of the warhead components. The goal is to render the materials in these components at least as unavailable or unattractive for use in future nuclear weapon production as materials which are commonly available in the civilian nuclear fuel cycle, such as low-enriched uranium or spent reactor fuel. In the case of high-enriched uranium, transparency measures have already been negotiated to verify that material from dismantled warheads is being converted into low-enriched uranium for civilian reactor fuel. Disposing of plutonium components will be more difficult.[14] The plutonium could be used to fabricate mixed-oxide fuel elements for civilian reactors, but the resulting fuel would be more expensive than fresh uranium fuel, and neither country has facilities to fabricate plutonium fuels. Alternatively, the plutonium could be mixed with vitrified high-level radioactive

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[13] A possible complication is the fact that warhead maintenance and remanufacturing activities might still be occurring at the facility. To deal with this, it might be best to segregate these activities. For example, Pantex could designate a certain area for maintenance and remanufacturing, and another area for dismantling. It would be necessary, of course, to verify that the maintenance facility wasn't being used to increase the stockpile, but this could be done by requiring a strict balance between the number of warheads and pits entering and exiting the maintenance facility. Some people worry that, by observing maintenance and remanufacturing activities, the monitoring party might learn of vulnerabilities in the force. If, for example, Russia observed that all the W-76 Trident warheads were being rebuilt, it might conclude that that system had a major reliability problem. Even so, it is difficult to see how that knowledge would confer a significant and usable military advantage. U.S. policy is to maintain a mix of warheads in the stockpile, so that the failure of any one system would not cripple the deterrent capability of the overall force.

[14] For a comprehensive discussion, see National Academy of Sciences, Committee on International Security and Arms Control, ***Management and Disposition of Excess Weapons Plutonium*** (Washington, DC: National Academy Press, 1994); and National Academy of Sciences, Committee on International Security and Arms Control, ***Management and Disposition of Excess Weapons Plutonium: Reactor-Related Options*** (Washington, DC: National Academy Press, 1995).

wastes. In either case, traditional IAEA-type safeguards should be able to verify that no plutonium has been diverted.

## **Reduction in Readiness**

Despite the end of the Cold War, the United States and Russia continue to maintain thousands of nuclear weapons on alert, ready to be launched within a few minutes of an order to do so. During the Cold War, both sides believed that the ability to launch nuclear forces quickly was a necessary and appropriate hedge against the possibility of a surprise attack against its nuclear forces. This was true despite that fact that both sides maintained—and still maintain—substantial forces that cannot be destroyed by a surprise attack.

The balance of risks has shifted decisively against such a posture in recent years. The fear of calculated attack by the Soviet Union has been superceded by a risk of accidental, unauthorized, or erroneous attack by Russia. Russia, to protect against the possibility of a sudden attack involving the thousands of U.S. warheads maintained on high alert, reportedly relies on its capacity to launch its ICBMs and pier-side SLBMs on warning of a missile attack. But Russia's attack warning system is seriously fragmented and degraded: only three of its nine modern radars are working at all, seven of the ten older "Hen House" radars lie outside Russian territory, and two of the nine slots in its constellation of early warning satellites are empty.[15] The dangers of this hair-trigger posture were illustrated when the launch of a harmless Norwegian scientific rocket triggered the first-ever activation of Yeltsin's "nuclear briefcase."[16]

Maintaining nuclear forces on high alert is difficult and dangerous enough in the best of conditions, but Russia is in the midst of a extended political and economic crisis that could worsen rapidly. Within the armed services, wages go unpaid for months, morale is low and corruption is high, and facility maintenance and personnel training are deferred. On several occasions electrical power has been cut off to strategic nuclear facilities because bills were not paid, and

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[15] Bruce G. Blair, "De-alerting Strategic Nuclear Forces," in Bruce Blair, Jonathan Dean, Harold Feiveson, Steve Fetter, James Goodby, George Lewis, Janne Nolan, Theodore Postol, and Frank von Hippel, ***The Nuclear Turning Point: A Blueprint for Deep Cuts and Dealerting of Nuclear Weapons*** (Washington, DC: The Brookings Institution, 1998).
[16] Bruce G. Blair, Harold A. Feiveson, and Frank N. von Hippel, "Taking Nuclear Weapons off Hair-Trigger Alert," ***Scientific American*** (November 1997), pp. 74-76.

communications have been disrupted because thieves were “mining” cables for valuable metals.[17]

The stain on both countries would be relieved if neither had to worry about the possibility of instant nuclear attack. The United States and Russia took a step in this direction by removing nuclear weapons from bombers, but more must be done. The launch-readiness of nuclear forces should be reduced in ways that are readily transparent to the other side, so that both sides can be assured that a large-scale surprise attack is not possible. Care must be taken, however, to do this in ways that do not create advantages—real or perceived—for quickly realerting forces or for striking first in a crisis.

In the near term, these goals could largely be achieved by maintaining a survivable force no larger than that required to fulfill the core deterrent mission, and by taking all other forces off alert. The core mission could be fulfilled by two to four submarines at sea, each armed with 50 to 100 warheads. These submarines need not—and should not—be capable of firing their missiles on short notice, but it might be difficult to demonstrate this to other countries without compromising their survivability. All other forces could be rendered incapable of rapid launch in ways that would be readily verifiable. For example, bombers could be based away from nuclear weapon storage areas. For ICBMs or in-port SLBMs, one could remove a key component, such as the shroud, guidance system, or warheads. For silo-based ICBMs, one also could obstruct or disable the silo door. Inspectors or remote monitoring devices could verify that missiles and bombers had not been readied for launch, and could provide timely warning of any attempt to do so.

The longer-term challenge is to verify that *all* delivery systems—even subs and mobile missiles on patrol—are incapable of being used quickly, without compromising their survivability or their ability to fulfill the core deterrent mission. It has been suggested, for example, that U.S. subs could patrol out of range of targets in Russia, but this would require that Russia be able to verify, on a more-or-less continuous basis, and in crisis as well as in peacetime, that U.S. subs had not moved within range. Although technical schemes can be envisioned that would make this possible—for example, requesting a particular sub to surface within a certain amount of time—it is likely that they would be resisted by the U.S. navy. Also, unlike U.S. subs, Russian subs normally do not patrol the open oceans, and doing so might compromise their survivability. Another concept relies on removing a key component, such as the guidance system, from the missiles aboard

[17] Blair, “De-alerting Strategic Nuclear Forces.”

the submarines. But how would Russia know at all times that the component had not been reinstalled? Similar questions arise with land-mobile ICBMs. This is an area where creative technical thinking is needed.

As a related confidence-building measure, the United States and Russia should adopt cooperative practices to assure each other that neither has launched or is preparing to launch a nuclear attack. Today, verification of alert status and warning of attack are provided solely by national technical means, such as photoreconnaissance and attack-warning satellites and early-warning radars. All five nuclear weapons states could gain from an evolving program to share such intelligence with each other, or to install sensors (video cameras, seismic sensors, and the like) near the nuclear forces of other states to verify their status. A program to exchange military officers also would enhance confidence over time in the low alert rate and benign intentions of the other countries.

**Shift in Strategy**

Despite the end of the Cold War, there is ample evidence that the United States and Russia cling to nuclear doctrines that emphasize early strikes on nuclear and command and control targets and attacks directed at the political and military leadership. A policy of targeting opposing nuclear forces for rapid destruction puts pressure on the other side to stand ready to launch its vulnerable forces (particularly ICBMs) on a few minutes notice, before these forces could be destroyed by a sudden attack. Fear of such attacks could trigger a launch of nuclear forces in response to a false warning, or a massive response to a small accidental or unauthorized attack.

A doctrine that provides for the rapid launch of nuclear forces during peacetime simply cannot be justified today, when the probability of an accidental or inadvertent launch may be far greater than the probability of a deliberate nuclear attack. Even an *option* to launch under attack is unwise, because it forces political and military leaders to make momentous decisions in a few minutes with very incomplete information on the nature or origin of the attack.

The United States and Russia should adopt strategies that would not call for prompt attacks on counterforce targets or imperil major fractions of the nation's population. Target planning might instead focus on major military facilities or core infrastructure such as energy network nodes located outside large urban areas. In all cases, plans should be designed to minimize civilian casualties, to reduce the pressure or incentives for escalation, and to allow political leaders to negotiate an end to nuclear attacks.

It is difficult to imagine how changes in targeting could be verified. War plans are carefully guarded secrets, and changes in them can at best be verified indirectly through corresponding changes in force posture. A dialogue between U.S. and Russian military leaders on this subject, combined with an expanded program of officer exchanges, could help pave the way toward greater mutual understanding.

**Demarcation of Defense**

A strong linkage exists between reductions in the size and readiness of offensive nuclear forces and limits on missile defenses. This linkage was captured in the preamble to the Anti-Ballistic Missile (ABM) Treaty, in which the United States and the Soviet Union agreed that

> Effective measures to limit anti-ballistic missile systems would be a substantial factor in curbing the race in strategic offensive arms and would lead to a decrease in the risk of outbreak of war involving nuclear weapons [and] . . . would contribute to the creation of more favorable conditions for further negotiations on limiting strategic arms.[18]

U.S. plans to develop and deploy systems capable of providing even a limited defense of the U.S. territory could weaken and possibly destroy the value of the ABM treaty. The Cold War may be over, but the United States and Russia will not agree to reduce their nuclear forces unless they are confident that the residual force could fulfill the core deterrent mission. If the United States deploys a system capable of intercepting missiles, Russia will take steps to ensure that its forces could penetrate the system. These steps could include refusing to implement provisions of the START agreements, increasing the number of deployed warheads, or increasing the readiness of its ICBMs and pier-side SLBMs to launch on warning of an attack. China’s small missile force would be more vulnerable to a missile defense, and it too might take steps to increase its offensive potential if the U.S. deployed a missile defense. It is precisely this sort of action-reaction syndrome that the ABM Treaty was designed to prevent.

Proponents of missile defense in the United States often point to the possibility of attacks by so-called “rogue” nations, such as North Korea or Iran. But current and foreseeable threats from these quarters are so limited that they do not justify deploying systems that would be capable of destroying Russian or Chinese missiles. In view of the limited nature of the missile threat, deployments of

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[18] U.S. Arms Control and Disarmament Agency, Arms Control and Disarmament Agreements: Texts and Histories of Negotiations (Washington, DC: U.S. ACDA, 1990), p. 157.

defensive systems should take place only if *all* the nuclear powers agree, at least tacitly, that such systems would not interfere with cooperative efforts to reduce the size and readiness of their nuclear forces. Otherwise, such deployments could be counterproductive, leading to a net decrease in security and stability.

Various technical constraints on missile-defense systems have been proposed to create a firebreak between tactical and strategic-capable defenses. Limits on the speed of interceptors or test warheads, intercept altitude, the number and geographical distribution of interceptors, sensor technology and integration, and the sale of technology to third parties should be investigated. Again, this is an area that is ripe for new and creative thinking.

## Conclusion: Technical Challenges in Verification

Because this is an audience of physicists, I'll conclude with a summary of the technical challenges for arms control verification that lie ahead.

- Nuclear archeology: how can one verify that a country has produced a certain number of nuclear weapons or a certain amount of high-enriched uranium or plutonium?

- Fingerprinting: how can one verify that a warhead or pit is authentic without revealing details about its construction?

- Dealerting: how can one verifying that a missile is incapable of firing without revealing its location or otherwise making it vulnerable to attack?

- Strategy: how can one verify that a country no longer plans to target its missiles against the nuclear forces and command and control systems of other countries?

- Demarcation: how can one verify that theater missile defense system do not pose a threat to the strategic missile forces of other countries?

Each of these challenges could benefit from creative and original thinking, and I hope that some of you will be stimulated try. Thank you.