# The End of MAD?

## The Nuclear Dimension of U.S. Primacy

*Keir A. Lieber and Daryl G. Press*

For nearly half a century, the world's most powerful nuclear-armed countries have been locked in a military stalemate known as mutual assured destruction (MAD). By the early 1960s, the United States and the Soviet Union possessed such large, well-dispersed nuclear arsenals that neither state could entirely destroy the other's nuclear forces in a first strike. Whether the scenario was a preemptive strike during a crisis, or a bolt-from-the-blue surprise attack, the victim would always be able to retaliate and destroy the aggressor. Nuclear war was therefore tantamount to mutual suicide. Many scholars believe that the nuclear stalemate helped prevent conflict between the superpowers during the Cold War, and that it remains a powerful force for great power peace today.[1]

The age of MAD, however, is waning. Today the United States stands on the verge of attaining nuclear primacy vis-à-vis its plausible great power adversaries. For the first time in decades, it could conceivably disarm the long-range

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1. Seminal works on the "nuclear peace" include Kenneth N. Waltz, *The Spread of Nuclear Weapons: More May Be Better*, Adelphi Papers No. 171 (London: International Institute for Strategic Studies, 1981); Kenneth N. Waltz, "Nuclear Myths and Political Realities," *American Political Science Review*, Vol. 84, No. 3 (September 1990), pp. 731–745; Robert Jervis, "The Political Effects of Nuclear Weapons: A Comment," *International Security*, Vol. 13, No. 2 (Fall 1988), pp. 80–90; Robert Jervis, *The Meaning of the Nuclear Revolution: Statecraft and the Prospect of Armageddon* (Ithaca, N.Y.: Cornell University Press, 1989); Stephen Van Evera, "Primed for Peace: Europe after the Cold War," *International Security*, Vol. 15, No. 3 (Winter 1990/91), pp. 7–57; and Stephen Van Evera, *Causes of War: Power and the Roots of Conflict* (Ithaca, N.Y.: Cornell University Press, 1999), chap. 8. John J. Mearsheimer is less optimistic than many other scholars about the future of great power peace, but he too agrees that nuclear weapons in the hands of great powers are "a force for peace." Mearsheimer, *The Tragedy of Great Power Politics* (New York: W.W. Norton, 2001), pp. 133, 380. Similarly, see Robert J. Art, *A Grand Strategy for America* (Ithaca, N.Y.: Cornell University Press, 2003), pp. 209–213.

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nuclear arsenals of Russia or China with a nuclear first strike. A preemptive strike on an alerted Russian arsenal would still likely fail, but a surprise attack at peacetime alert levels would have a reasonable chance of success. Furthermore, the Chinese nuclear force is so vulnerable that it could be destroyed even if it were alerted during a crisis. To the extent that great power peace stems from the pacifying effects of nuclear weapons, it currently rests on a shaky foundation.

This article makes three empirical claims. First, the strategic nuclear balance has shifted dramatically since the end of the Cold War, and the United States now stands on the cusp of nuclear primacy.[2] Second, the shift in the balance of power has two primary sources: the decline of the Russian nuclear arsenal and the steady growth in U.S. nuclear capabilities. Third, the trajectory of nuclear developments suggests that the nuclear balance will shift further in favor of the United States in the coming years. Russia and China will face tremendous incentives to reestablish mutual assured destruction, but doing so will require substantial sums of money and years of sustained effort. If these states want to reestablish a robust strategic deterrent, they will have to overcome current U.S. capabilities, planned improvements to the U.S. arsenal, and future developments being considered by the United States. U.S. nuclear primacy may last a decade or more.

To illustrate the shift in the strategic nuclear balance, we model a U.S. nuclear first strike against Russia. Russia was not chosen because it is the United States' most likely great power adversary; to the contrary, most analysts expect China to fill that role. But Russia presents the hardest case for our contention that the United States is on the brink of nuclear primacy. It has about 3,500 nuclear warheads capable of reaching the continental United States; by comparison, China has only 18 single-warhead missiles that can reach the U.S. homeland.[3] If the United States can destroy all of Russia's long-range nuclear systems in a first strike—as we argue it could possibly do today—it suggests that the Chinese strategic nuclear arsenal is far more vulnerable.

Our model does not prove that a U.S. disarming attack against Russia would succeed. Nor does the model assume that the United States is likely to launch a nuclear first strike. Even if U.S. leaders were highly confident of success, a

2. We use the term "nuclear primacy" to describe the situation in which the one country with primacy can destroy its adversary's nuclear retaliatory capabilities in a disarming strike. A shorter version of our argument appears in Keir A. Lieber and Daryl G. Press, "The Rise of U.S. Nuclear Primacy," *Foreign Affairs,* Vol. 85, No. 2 (March/April 2006), pp. 42–54.

3. Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2006," *Bulletin of the Atomic Scientists*, Vol. 62, No. 2 (March/April 2006), pp. 64–67; and Jeffrey Lewis, "China's Arsenal, By the Numbers," *Bulletin of Atomic Scientists*, Vol. 61, No. 3 (May/June 2005), p. 55. The only Chinese nuclear weapons that can reach the continental United States are 18 DF-5 ICBMs.

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counterforce strike would entail enormous risks and costs. Rather, the model demonstrates that Russian (and Chinese) leaders can no longer count on having a survivable nuclear deterrent.

This analysis challenges the prevailing optimism among scholars from all three major international relations traditions about the future of great power peace. For realists, optimism rests largely on the strategic stalemate induced by MAD.[4] Liberal scholars, on the other hand, find substantial reason for optimism in the pacifying effects of democracy, economic interdependence, and international institutions.[5] But nuclear deterrence plays a supporting role for them as well. For example, several prominent liberals note that nuclear deterrence prevents states from seizing wealth and power by conquering their neighbors; trade and broader economic cooperation have become the only foreign policy strategies for amassing economic might.[6] Similarly, some leading constructivists contend that nuclear weapons have rendered major power war so futile that the entire enterprise has been socialized out of the international system.[7] One scholar argues that the nuclear stalemate dampens states' security fears and allows them to pursue collective goals, develop shared identities, and create a culture of trust.[8] Our analysis, however, pulls away one leg from these arguments.[9] Nuclear weapons may no longer produce the peace-inducing stalemate that they did during the Cold War.[10]

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4. See n. 1 above.
5. See, for example, Bruce Russett and John R. Oneal, *Triangulating Peace: Democracy, Interdependence, and International Organizations* (New York: W.W. Norton, 2001).
6. Klaus Knorr, *On the Uses of Military Power in the Nuclear Age* (Princeton, N.J.: Princeton University Press, 1966); Richard N. Rosecrance, *The Rise of the Trading State: Commerce and Conquest in the Modern World* (New York: Basic Books, 1986); and Richard N. Rosecrance, *The Rise of the Virtual State: Wealth and Power in the Coming Century* (New York: Basic Books, 1999).
7. Although Nina Tannenwald argues that a "nuclear taboo" has effectively rendered nuclear weapons obsolete, she writes, "More paradoxically, the taboo has also helped to stabilize, rather than undermine, mutual nuclear deterrence between the superpowers, not by any technical means but by helping to embed deterrence in a set of shared practices, institutions, and expectations." Tannenwald, "Stigmatizing the Bomb: Origins of the Nuclear Taboo," *International Security*, Vol. 29, No. 4 (Spring 2005), pp. 5–49, at p. 41. John Mueller explicitly discounts the necessity of nuclear weapons in rendering great power war obsolete, but acknowledges that they provide "extra insurance" against the likelihood of war. Mueller, "The Essential Irrelevance of Nuclear Weapons: Stability in the Postwar World," *International Security*, Vol. 13, No. 2 (Fall 1988), pp. 55–79, at p. 69.
8. Alexander Wendt, *Social Theory of International Politics* (New York: Cambridge University Press, 1999), pp. 357–363. See also Emanuel Adler and Michael Barnett, "A Framework for the Study of Security Communities," in Adler and Barnett, eds., *Security Communities* (Cambridge: Cambridge University Press, 1998), p. 38.
9. Not all scholars have faith in nuclear deterrence, even among the great powers. For example, Scott D. Sagan uses theories of organizational politics to challenge the rational framework underlying optimism about nuclear deterrence. Sagan's arguments are powerful, and they have even greater force when nuclear arsenals are actually vulnerable to attack, as we argue here. See Sagan and Kenneth N. Waltz, *The Spread of Nuclear Weapons: A Debate Renewed* (New York: W.W. Norton, 2003), chaps. 2, 3, 5.
10. Many scholars would be skeptical about the reemergence of great power conflict even with the

Our findings should lead U.S. decisionmakers and foreign policy analysts to consider the wisdom of continued improvements to the U.S. nuclear arsenal. On the one hand, nuclear primacy may convey significant benefits to the United States: it may give U.S. leaders coercive leverage over adversaries in future high-stakes crises, as it did during several Cold War crises before the age of MAD.[11] On the other hand, nuclear primacy may substantially reduce U.S. security. Growing U.S. capabilities will pressure Russia and China to reduce the peacetime vulnerability of their forces by building larger nuclear arsenals, dispersing their nuclear forces, possibly predelegating launch authority to local commanders, and perhaps adopting hair-trigger nuclear retaliatory doctrines. These precautionary steps by Russia and China are logical, but they may precipitate a new nuclear arms race.[12] Even worse, the nuclear imbalance may create dangerous instability during crises or wars. If, for example, China does not sufficiently reduce its peacetime vulnerability, it will feel compelled to do so during a conflict with the United States. However, a frantic Chinese nuclear alert during ongoing military operations (e.g., during a war over Taiwan) could lead to crisis dynamics (e.g., U.S. fears that China is preparing to escalate, and resulting temptations to preempt) more dangerous than those seen for decades.[13]

The shift in the nuclear balance highlights the need for international security

absence of nuclear deterrence, but they underestimate the dangers resulting from the rise of China. Historically, periods of power transition have been tumultuous and war prone. Others factors also suggest that China's rise will lead to a serious Sino-U.S. rivalry: China has poor relations with key U.S. allies in the region (e.g., Japan); it is ruled by an authoritarian government (so the democratic peace does not apply); and many U.S. foreign policy analysts already view China as the biggest long-term threat to the United States. The principal reason to expect a peaceful power transition is the shared security provided by MAD. The analysis in this article, however, weakens the basis for this optimism. On the dangers of power transitions, see Robert Gilpin, *War and Change in International Politics* (New York: Cambridge University Press, 1981); and Dale C. Copeland, *The Origins of Major War* (Ithaca, N.Y.: Cornell University Press, 2000). On the importance of nuclear deterrence for avoiding a serious U.S.-China conflict, see Avery Goldstein, "Great Expectations: Interpreting China's Arrival," *International Security*, Vol. 22, No. 3 (Winter 1997/98), pp. 70–71.

11. Marc Trachtenberg, *A Constructed Peace: The Making of the European Settlement, 1945–1963* (Princeton, N.J.: Princeton University Press, 1999), pp. 89–90; and Melvyn P. Leffler, *A Preponderance of Power: National Security, the Truman Administration, and the Cold War* (Stanford, Calif.: Stanford University Press, 1992), p. 326. For an analysis of the impact of nuclear primacy and stalemate on Cold War crisis behavior, see Daryl G. Press, *Calculating Credibility: How Leaders Assess Military Threats* (Ithaca, N.Y.: Cornell University Press, 2005), chaps. 3–4; and Keir A. Lieber, *War and the Engineers: The Primacy of Politics over Technology* (Ithaca, N.Y.: Cornell University Press, 2005), chap. 5.

12. On the steps that the Cold War superpowers took to enhance the survivability of their forces, see Paul Bracken, *The Command and Control of Nuclear Forces* (New Haven, Conn.: Yale University Press, 1983); and Kurt Gottfried and Bruce G. Blair, eds., *Crisis Stability and Nuclear War* (New York: Oxford University Press, 1988).

13. On the dangers of inadvertent nuclear escalation resulting from conventional military operations, see Barry R. Posen, *Inadvertent Escalation: Conventional War and Nuclear Risks* (Ithaca, N.Y.: Cornell University Press, 1991).

scholars to address two questions that have been overlooked since the end of the Cold War. First, does nuclear primacy grant the superior side real coercive leverage in political disputes? And, second, how survivable must a country's nuclear arsenal be for the "nuclear peace" to hold sway? In other words, are potentially vulnerable nuclear arsenals sufficiently terrifying to deter almost any attack, or does stable deterrence require large invulnerable retaliatory forces? These questions were hotly contested during the Cold War, but their policy relevance and research tractability are greater today than ever before. Not only is nuclear primacy again within the grasp of one country, but also the archives in Western and some previously Communist bloc countries now contain reliable, declassified documentary evidence on the strategic calculations of leaders in the previous era of nuclear primacy and during the most intense Cold War nuclear crises.

The first section of this article describes the causes of the shift in the strategic balance of power. The second section models a U.S. nuclear first strike on Russia as a hard case for our argument that the United States is on the cusp of nuclear primacy. In the third section, we examine current trends in the nuclear balance and argue that U.S. nuclear superiority will grow in the short-to-medium term. The fourth section describes the implications of U.S. nuclear primacy and evaluates several counterarguments.

## *How the Nuclear Balance Shifted, 1990–2004*

From the early 1960s through the end of the Cold War, the strategic nuclear balance among the great powers was characterized by mutual assured destruction. Any attack by one side against another would leave the victim with more than enough deliverable nuclear warheads to exact terrible retribution against the aggressor's homeland. Analysts debated the state of the nuclear balance throughout the 1970s and 1980s but, revealingly, they focused on the ability of the Soviet Union to destroy merely one leg of the U.S. nuclear triad (the land-based missile force). Since the early 1960s, no credible analysis has suggested that a nuclear first strike could destroy the entire American or Soviet nuclear arsenals.[14] For example, the best unclassified analysis of the nuclear balance in the 1980s predicted that a surprise U.S. disarming strike would leave the

14. For an excellent review of the Cold War debates over the nuclear balance, see Michael Salman, Kevin J. Sullivan, and Stephen Van Evera, "Analysis or Propaganda? Measuring American Strategic Nuclear Capability, 1969–88," in Lynn Eden and Steven E. Miller, eds., *Nuclear Arguments: Understanding the Strategic Nuclear Arms and Arms Control Debates* (Ithaca, N.Y.: Cornell University Press, 1989), pp. 172–263.

Soviets with more than 800 surviving warheads—more than enough to inflict a "disaster beyond history" upon the United States.[15]

In the last fifteen years, however, the strategic nuclear balance has shifted profoundly. Part of the shift is attributable to the decline of the Russian arsenal. Compared with the Soviet force in 1990, Russia has 58 percent fewer intercontinental ballistic missiles (ICBMs), 39 percent fewer bombers, and 80 percent fewer ballistic missile submarines (SSBNs).[16] Furthermore, serious maintenance and readiness problems plague Russia's nuclear forces. Most of Russia's ICBMs have exceeded their service lives, and a series of naval accidents—highlighted by the sinking of the attack submarine *Kursk* in 2000—reflect the severe decay of the fleet.[17] Budgetary constraints have also dramatically reduced the frequency of Russia's submarine and mobile ICBM patrols, increasing the vulnerability of what would otherwise be the most survivable element of its arsenal. Since 2000, Russian SSBNs have conducted approximately two patrols per year (with none in 2002), down from sixty in 1990, and apparently Russia often has no mobile missiles on patrol.[18] Finally, Russia has had difficulty maintaining satellite observation of U.S. ICBM fields, and gaps in its radar network would leave it blind to a U.S. submarine-launched ballistic missile (SLBM) attack from launch areas in the Pacific Ocean.[19]

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15. Ibid., pp. 221–227.
16. Natural Resources Defense Council, "USSR/Russian Strategic Offensive Force Loadings, 1956–2002," http://www.nrdc.org/nuclear/nudb/datainx.asp; and Norris and Kristensen, "Russian Nuclear Forces, 2006," p. 65.
17. Pavel Podvig runs an excellent website (http://www.russianforces.org) with current and archived news and commentary on the status of Russia's nuclear forces. On Russia's ongoing maintenance and readiness problems, see Podvig, "Borey Submarine Launch Postponed until 2007," November 22, 2005, http://russianforces.org/eng/blog/archive/000646.shtml; Podvig, "More Delays with Submarine Construction," July 28, 2005, http://russianforces.org/eng/blog/archive/000573.shtml; Norris and Kristensen, "Russian Nuclear Forces, 2006," p. 64; Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2005," *Bulletin of the Atomic Scientists*, Vol. 61, No. 2 (March/April 2005), pp. 70–72; Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2004," *Bulletin of the Atomic Scientists*, Vol. 60, No. 4 (July/August 2004), pp. 72–74; Matthew G. McKinzie, Thomas B. Cochran, and Robert S. Norris, *The U.S. Nuclear War Plan: A Time for Change* (Washington, D.C.: Natural Resources Defense Council, 2001), pp. 61–68; and Bruce Blair and Clifford Gaddy, "Russia's Aging War Machine: Economic Weakness and the Nuclear Threat," *Brookings Review*, Vol. 17, No. 3 (Summer 1999), pp. 10–13.
18. On Russian SSBN patrols, see Hans M. Kristensen, "Russian Nuclear Submarine Patrols," Nuclear Information Project Nuclear Brief, August 3, 2005, http://www.nukestrat.com/russia/subpatrols.htm. Less data are available on the patrol rate of Russian mobile missiles, but the best information suggests that Russia frequently relies on in-garrison alerts for its mobile ICBMs rather than patrols. Personal communication with Hans M. Kristensen, January 13, 2006.
19. A Russian general recently described the Russian satellite constellation as "hopelessly outdated." He complained that Russia's space forces did not have the resources to bring the early warning constellation to even the "minimum necessary" level. Quoted in Pavel Podvig, "Hopelessly Outdated," November 21, 2005, http://russianforces.org/eng/blog/archive/000641.shtml. On gaps in the Russian ground-based radar, see Pavel Podvig, "History and the Current Status of the Russian Early-Warning System," *Science and Global Security*, Vol. 10, No. 1 (January 2002), pp.

While the Russian strategic arsenal has eroded, the United States has continued to modernize its weapons. U.S. strategic forces have shrunk in number since the end of the Cold War, but they have become more lethal. The U.S. submarine force has undergone nearly continuous improvement over the past fifteen years. The deployment of the highly accurate Trident II (D-5) SLBM was a Cold War decision, but the United States stuck with the deployment plans and has steadily refitted its entire SSBN fleet to carry the new missile.[20] Furthermore, the United States has significantly increased the lethality of the original Trident II missile against hard targets such as missile silos: the navy replaced nearly 400 of the 100-kiloton W76 warheads on these missiles with the more powerful 455-kiloton W88 warhead, creating an incredibly lethal combination of accuracy and warhead yield. Other upgrades to Trident II include a more accurate reentry vehicle (RV) and other improvements to increase the missile's accuracy.[21]

The United States has also been upgrading its land-based missiles and strategic bombers. Although the United States finished dismantling the MX Peacekeeper ICBM in 2005 in accordance with its arms control commitments, the key elements that gave the MX exceptional lethality are being preserved. The nuclear warheads and advanced RVs from the MX are beginning to replace the lower-yield warheads and less accurate RVs on 200 Minuteman III ICBMs. In addition, the Minuteman guidance systems have been upgraded to roughly match the accuracy of the retired MX.[22] In another example of U.S. force modernization, the B-2 bomber has been given upgraded avionics that allow it to avoid radar by flying at extremely low altitude.[23] At first glance, this seems like a strange capability to give the B-2: the aircraft is so stealthy that it seems hard to justify the risks of very low altitude flight (e.g., crashing into the ter-

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21–60. When Podvig wrote his article, Russia was blind to a nuclear attack from U.S. submarines stationed in both the Atlantic and the Pacific. Since 2002 Russia has partially plugged the west-facing hole in its radar network, but attacks from certain launch areas in the Atlantic would give Russia very short warning before impact. Russia is still blind to a submarine attack from launch areas in the Pacific. See also Pavel Podvig, "If It's Broke, Don't Fix It," *Bulletin of the Atomic Scientists*, Vol. 61, No. 4 (July/August 2005), pp. 21–22.

20. "UGM-133 Trident D-5," *Jane's Strategic Weapon Systems* (Surrey, U.K.: Jane's Information Group, August 2004); and *Jane's Strategic Weapon Systems* (Surrey, U.K.: Jane's Information Group, September 2005).

21. Ibid.; "Trident II D-5 Fleet Ballistic Missile," http://www.globalsecurity.org/wmd/systems/d-5.htm; and Theodore A. Postol, "The Nuclear Danger from Shortfalls in the Capabilities of Russian Early Warning Satellites: A Common Russian-U.S. Interest for Security Cooperation," presentation at the Massachusetts Institute of Technology's Lincoln Laboratory, April 12, 1999.

22. Norris and Kristensen, "U.S. Nuclear Forces, 2006," *Bulletin of the Atomic Scientists*, Vol. 62, No. 1 (January/February 2006), p. 68; and "LGM-30G Minuteman III," *Jane's Strategic Weapon Systems* (Surry, U.K.: Jane's Information Group, August 2004).

23. "B-2 Upgrades," http://www.globalsecurity.org/wmd/systems/b-2-upgrades.htm.

rain) to reduce the bomber's exposure to radar. However, against an adversary with an extremely sophisticated air defense network (e.g., Russia today or China in the future), very low-level flight may be necessary to penetrate enemy airspace.

## *A Surprise U.S. Nuclear Attack on Russian Strategic Forces*

Modeling a U.S. nuclear attack on Russia requires (1) data on the likely targets of such an attack; (2) data on the number and capabilities of U.S. weapons; (3) a plan that allocates weapons to targets; and (4) formulas for estimating the likely results of the attack. Two other crucial issues in nuclear targeting are the problem of nuclear "fratricide" and the question of whether Russia would be able to launch a retaliatory attack before U.S. weapons arrived at their targets.

### THE TARGETS: RUSSIA'S STRATEGIC NUCLEAR FORCES

The highest priority targets in a U.S. nuclear attack on Russia would be the long-range weapons that Russia could use to retaliate. Other targets would be hit as well: for example, nuclear storage sites, short-range nuclear forces, conventional military forces, and command and control sites.[24]

Russia's strategic nuclear forces can be divided into four categories. The first comprises 258 ICBMs deployed in silos that have been hardened enough that each must be targeted individually.[25] The second leg is Russia's 291 mobile long-range missiles. If alerted, these missiles would disperse across large patrol areas, making them difficult to destroy. Normally, however, they are kept in shelters inside forty garrisons.[26] The third leg comprises 78 long-range

24. An alterative approach for a disarming strike would focus on Russia's nuclear command and control system rather than its long-range strategic forces. During the Cold War, nuclear war planners and analysts considered such "decapitation" strategies. In this analysis, we demonstrate that an attack aimed directly at Russia's strategic arsenal is growing increasingly feasible. Because we do not model an attack on Russia's command and control system, our results are a lower-bound estimate of U.S. offensive nuclear capabilities: Russia's arsenal may be even more vulnerable than our findings suggest. For a Cold War analysis of command and control vulnerability, see Bruce Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington, D.C.: Brookings, 1985).

25. Norris and Kristensen, "Russian Nuclear Forces, 2006," p. 65.

26. On the low frequency of SS-25 patrols, personal communication with Kristensen. Note that even when the Russians do conduct mobile missile patrols, the deployed force is typically only a regiment (9 missile launchers). With such a small number of deployed missiles, a disarming strike could succeed. The United States likely spends considerable effort studying the deployments of Russian mobile ICBMs and is openly working to improve its capabilities to track elusive targets such as mobile missile launchers. In a future study, we will consider the feasibility of various U.S. targeting strategies against Russian and Chinese mobile ICBMs, including the use of a nuclear "barrage attack" against their deployment areas.

bombers that are normally deployed at two air force bases. Seven other airfields are used for training and exercises, so they too are primary targets. In addition, fifty-four other airfields have a connection to Russia's bomber force and are included on the target list.[27] The last leg is Russia's submarine force. Russia has 12 SSBNs, although only 9 are currently in service; and it has dramatically reduced the frequency of routine patrols. In fact, Russia usually has no SSBNs at sea, relying instead on a dock-alert system in which a submarine in port is on alert.[28] Russia's SSBNs are deployed at three main bases; several dozen other naval facilities are occasionally visited by submarines, however, and would also have to be attacked.[29] Finally, we target 127 nuclear weapons storage, production, assembly, and disassembly sites.[30] Table 1 summarizes the current Russian strategic force and estimates the number of aimpoints that would have to be targeted to destroy each leg of that force.

### FORCES FOR A U.S. NUCLEAR FIRST STRIKE

The United States currently fields 500 ICBMs, 14 SSBNs, and 77 strategic bombers. The size of this arsenal is bigger than these numbers suggest because most U.S. missiles, submarines, and bombers carry multiple warheads. For example, a single U.S. SSBN carries (on average) 144 warheads. Each B-2 bomber can carry 16 nuclear bombs, and the B-52 bombers have room for 20 nuclear-armed cruise missiles.[31]

Not all of these forces, however, are typically available for a first strike. During normal conditions, approximately 95 percent of U.S. ICBMs are prepared to launch, but the other legs of the triad are kept at lower alert levels. Typically only 4 SSBNs are on routine patrol, and no U.S. bombers are kept on alert for nuclear operations.[32]

The United States could take steps to surreptitiously increase the size of the alert force. For example, although there are usually only 4 U.S. SSBNs on patrol, occasionally there are submarines (1) traveling to replace those on station, (2) returning to port after a patrol, and (3) training at sea for an upcoming de-

27. McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, pp. 82–84.
28. Kristensen, "Russian Nuclear Submarine Patrols"; and Podvig, "Current Status of the Strategic Forces."
29. Podvig, "Current Status of the Strategic Forces"; and McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, pp. 65–73.
30. McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, pp. 89–102.
31. Norris and Kristensen, "U.S. Nuclear Forces, 2006"; and "United States Nuclear Forces," http://www.globalsecurity.org/wmd/systems/index.html.
32. McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, pp. 89–102, 18–20. These data on U.S. force readiness are consistent with the entries on the *GlobalSecurity.org* and Federation of American Scientists (2006) websites for Minuteman ICBMs, B-2 bombers, and B-52 bombers.

**Table 1. Russian Long-Range Nuclear Systems and Targets in a U.S. First Strike**

| Type | Name | Number | Number of Targets | Notes |
|---|---|---|---|---|
| Silo-based ICBMs | SS-18<br>SS-19<br>SS-27 | 85<br>129<br>44 | 85 silos<br>129 silos<br>44 silos | SS-18 silos estimated to withstand 3,000 pounds per square inch (psi) overpressure; others 5,000 psi |
| Mobile ICBMs | SS-25 | 291 | 40 garrisons | Mobile missiles; 40 squadrons; normally kept in garrison; hardened shelters |
| Ballistic missile submarines | Delta III<br>Delta IV | 6<br>3 | 3 primary ports | Submarines rarely deploy; usually none at sea; some stay on alert at dock |
| Strategic bombers | Bear and<br>Blackjack | 64<br>14 | 9 primary and 54 secondary airfields | Two major bomber bases plus seven support airfields and 54 dispersal fields |
| Storage/ assembly sites | | 127 | 127 facilities | Includes storage sites, production, assembly, and disassembly facilities |

SOURCES: These data are from Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2006," *Bulletin of the Atomic Scientists,* Vol. 62, No. 2 (March/April 2006), pp. 64–67. The numbers are in flux as the Russian force contracts. For the latest information on Russian forces, see Pavel Podvig, "Current Status of the Strategic Forces," http://www.russianforces.org/eng/. Data on Russian submarine ports, airfields, and nuclear storage sites are from Matthew G. McKinzie, Thomas B. Cochran, and Robert S. Norris, *The U.S. Nuclear War Plan: A Time for Change* (Washington, D.C.: Natural Resources Defense Council, 2001).

NOTE: Each silo-based ICBM presents a unique target because the silos are too hard to allow for multiple kills with a single warhead. The 291 SS-25s present only 40 targets when they are in their garrisons because a single warhead could destroy the shelters. See analysis in appendix 1. The 9 Russian ballistic missile submarines are typically distributed among 3 submarine bases. The exact mix of Delta III and Delta IV submarines is in transition; the Delta IIIs are reportedly going to be retired and replaced by Delta IV boats, 3 of which are currently being overhauled. Russia has 78 strategic bombers that are deployed at 2 bases; there are 7 other airfields associated with their strategic bombers and 54 other airfields that would likely be struck; these include possible dispersal bases for the long-range bombers.

ployment. The United States could secretly order SSBNs heading home from patrol to return to their launch areas, order the submarines on patrol to remain on station after their replacements arrive, and send submarines undergoing predeployment training to launch areas. If timed cleverly, the only sign of the "surge" in U.S. naval activity would be a submarine or two returning late from patrol. In the model below, we assume a temporary surge of 8 SSBNs at sea.

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The U.S. strategic bomber force would be easier to alert quietly. Given the small number of aircraft involved, the United States should be able to perform preflight maintenance and load the planes with bombs and cruise missiles without taking externally visible steps. In the model, we assume that the United States can quietly alert 75 percent of the small bomber force (58 bombers plus tankers for aerial refueling).

To estimate the number of nuclear warheads that the United States could launch against an adversary, one additional calculation is required: the reliability of U.S. delivery systems (i.e., missiles, submarines, and aircraft). Our model uses the standard estimate of 80 percent reliability for U.S. nuclear weapon systems;[33] we vary this assumption in our sensitivity analysis.

Table 2 provides a snapshot of the U.S. strategic force with information on weapon yield and accuracy. Weapon yields are widely reported, but there is greater uncertainty about accuracy. Our estimates of accuracy use publicly available data; when sources conflict, we generally use the most recent estimates because key components of these weapons are occasionally updated to improve performance.

### Assigning weapons to targets and estimating effects

In assigning U.S. weapons to Russian targets, we follow three principles: (1) the most accurate weapons are assigned to the hardest targets; (2) the fastest-arriving weapons are assigned to the targets capable of responding most quickly;[34] and (3) except for the nuclear storage sites, each target must be hit by at least one fast-arriving weapon. The goal is to ensure that each target is at least damaged in the initial, surprise wave of warheads; follow-on waves would arrive minutes later to ensure that virtually every target is destroyed. Finally, the attack we model leaves the United States with a reserve of more than 350 strategic nuclear warheads ready to be fired immediately after the U.S. first strike; the number of available strategic warheads would rise quickly to more than 1,000 as bombers returned and reloaded; and the submarines that did not attack (because they were in port) pushed out to sea.

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33. See, for example, similar assumptions in Salman, Sullivan, and Van Evera, "Analysis or Propaganda?" pp. 260, 263.

34. "Fast arriving" is judged by the time it takes the warhead to travel from the point of earliest detection to the target. By this criterion, slow-moving stealthy cruise missiles (which may not be detected at all before detonation) and SLBM warheads are fast arriving. Even if Russia plugs the holes in its missile-warning network, incoming SLBMs would be detected only a few minutes before impact; with the current holes, there may be no warning.

**Table 2. U.S. Strategic Weapon Systems and Key Characteristics**

| Type | Number | Available | Available Warheads | Yield (kilotons) | Accuracy (meters) | Notes |
|---|---|---|---|---|---|---|
| Ohio-class SSBN (D-5) | 12 | 8 | 1,152 | 455<br>100 | 90 | Very accurate; fast to target |
| Ohio-class SSBN (C-4) | 2 | Currently being converted to D-5. Not used in attack. | | | | |
| Minuteman III ICBM (W78) | 300 | 285 | 713 | 335 | 120 | Very accurate; 30-minute flight to target |
| Minuteman III ICBM (W62) | 200 | 190 | 285 | 170 | 180 | Very accurate; 30-minute flight target |
| B-2 bomber (B83) | 21 | 16 | 256 | 1,200 | 150 | Stealthy aircraft; might reach targets undetected |
| B-52 bomber (AGM-86/ AGM-129) | 56 | 42 | 840 | 150 | 30 | Carry stealthy and nonstealthy cruise missiles |
| Total | | | 3,246 | | | |

SOURCES: Robert S. Norris and Hans M. Kristensen, "U.S. Nuclear Forces, 2006," *Bulletin of the Atomic Scientists,* Vol. 62, No. 1 (January/February 2006), pp. 68–71; Duncan Lennox, ed., *Jane's Strategic Weapon Systems* (Surrey, U.K.: Jane's Information Group, 2004); and Robert Hewson, ed., *Jane's Air-Launched Weapons* (Surrey, U.K.: Jane's Information Group, 2002), pp. 239–241, 252, 502–503; and "U.S. Nuclear Forces," http://www.globalsecurity.org/wmd/systems/index.html.

NOTE: The "Number" column gives the total in the arsenal (except the entry for B-52s, which gives the number assigned to operational squadrons). The column marked "Available" gives an estimate of the number of submarines, missiles, or bombers that can be alerted without warning Russia. The "Available Warhead" column indicates the number of warheads carried by the "alertable" portion of the force; this is the number available for a nuclear first strike. The accuracy of each weapon is defined by the circular error probable, which is the median miss distance. SSBN is a ballistic missile submarine, and "D-5" and "C-4" refer to the missiles that they carry. Only submarines carrying D-5 missiles are used in the attack. Each U.S. SSBN carries 24 missiles, averaging 6 warheads per missile. Approximately 64 of these missiles are armed with W88 warheads, which have a 455-kiloton yield; the rest carry W76 warheads (100 kilotons). The ICBMs are Minuteman IIIs; 300 of them carry 750 W78 warheads; the other 200 missiles carry 300 W62 warheads. Those carrying W78 warheads have improved guidance systems and better accuracy. The B-2 bombers are assumed to carry B83 nuclear bombs, which have a 1,200-kiloton yield. The B-52 bombers carry single-warhead cruise missiles: either 20 AGM-86 cruise missiles or a mixed load of 8 AGM-86 and 12 AGM-129 stealthy cruise missiles.

Following the targeting criteria described above, we allocate U.S. nuclear weapons to Russian forces as follows:

Russian silo-based ICBMs:
- initial attacks: stealthy cruise missiles, B-2 strikes, and SLBM warheads
- follow-on attacks: land-based ICBMs

Russian mobile missile garrisons:
- initial attacks: multiple SLBM warheads
- follow-on attacks: ICBM warheads

Russian strategic aviation:
- initial attacks: SLBM warheads used for airbursts over airfields
- follow-on attacks: cruise missiles and ICBMs to crater runways

Russian naval facilities:
- initial attacks: multiple SLBM warheads against naval targets
- follow-on attacks: cruise missiles and ICBMs

Nuclear storage sites:
- initial attacks: no fast-arriving warheads
- follow-on attacks: ICBMs against storage facilities

Table 3 presents a list of targets in the hypothetical U.S. counterforce attack, the number of aimpoints for each target, and the number of warheads assigned to each aimpoint.

To calculate the expected outcome of this attack, we use variations of two simple formulas. The first uses the yield of a warhead and the hardness of a target to calculate the lethal radius (LR), that is, the maximum distance from the detonation at which the target would be damaged or destroyed. Once the LR is calculated, the second formula uses a given delivery vehicle's accuracy to calculate the odds (the "single-shot probability of kill," or SSPK) that it would deliver its warhead within the lethal radius.[35] (For details regarding these calculations, see appendix 1.)

Two clarifications about these calculations are necessary. First, this analysis assumes that Russia is unable to launch its missiles before the first wave of U.S. warheads arrive on target. For reasons described below, this assumption

35. These formula are (1) $LR = 2.62 \times Y^{0.33} / H^{0.33}$, and (2) $SSPK = 1 - 0.5^{(LR/CEP)\wedge 2}$. The variable $Y$ is the warhead yield in megatons and $H$ is the target's hardness in psi. CEP (circular error probable) is a measure of accuracy; it is the median miss distance. The seminal unclassified work on the effects of nuclear weapons is Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons* (Washington, D.C.: U.S. Government Printing Office, 1977). See also Lynn E. Davis and Warner R. Schilling, "All You Ever Wanted to Know about MIRV and ICBM Calculations but Were Not Cleared to Ask," *Journal of Conflict Resolution*, Vol. 17, No. 2 (June 1973), pp. 207–242.

**Table 3. Notional U.S. Nuclear Counterforce Strike on Russia**

| Target Type | Number | Aimpoints | Warheads per Aimpoint | Total Warheads |
|---|---|---|---|---|
| Silo-based ICBMs | 258 | 258 | 6–7 | 1,640 |
| Mobile ICBMs | 291 | 40 | 7 | 280 |
| Primary strategic airfields | 9 | 27 | 4 | 108 |
| Secondary airfields | 54 | 54 | 2 | 108 |
| Primary naval targets | 3 | 30 | 5 | 150 |
| Secondary naval targets | 31 | 107 | 3 | 321 |
| National nuclear storage sites | 17 | 136 | 1 | 136 |
| Regional storage sites | 33 | 66 | 1 | 66 |
| Other nuclear storage sites | 73 | 73 | 1 | 73 |
| Warhead assembly sites | 4 | 8 | 1 | 8 |
| Total | 773 | 799 | | 2,890 |

is realistic. Second, the model assumes that Russia's 9 deployed SSBNs are in port (or that one submarine is at sea but is being tracked) and that their mobile ICBMs are in garrison. For reasons described above, this assumption is also realistic.

### nuclear targeting and "fratricide"

Historically, analysts have assumed that only 2 nuclear warheads could be used in a short time frame against any target because of a problem called "fratricide." Assigning multiple warheads to a target requires precise timing to prevent one incoming warhead from destroying others. Furthermore, a nuclear detonation near ground level (which is ideal for destroying hardened silos) would create a debris cloud that could destroy other warheads heading to the same target. As a result, analysts have typically assumed that targets will be hit with a single airburst (which would create little debris) and a single ground burst.[36]

Concerns about fratricide were justified during the Cold War, but they no longer prevent planners from allocating multiple warheads to each target. The fratricide problem was serious during the Cold War because missiles did not have the pinpoint accuracy that they do today. Under those circumstances, at-

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36. John D. Steinbruner and Thomas M. Garwin, "Strategic Vulnerability: The Balance between Prudence and Paranoia," *International Security*, Vol. 1, No. 1 (Summer 1976), 138–181; and Matthew Bunn and Kosta Tsipis, "The Uncertainties of Preemptive Nuclear Attack," *Scientific American*, Vol. 249, No. 11 (November 1983), pp. 38–47.

tacks on an enemy's ICBM field would produce many near misses (i.e., warheads that detonated too far from the silo to destroy it, but close enough to create a debris cloud that would shield it from the next wave of attacks). Today U.S. missile accuracy is so good that virtually all misses would result from delivery-vehicle malfunctions rather than accuracy limitations; the key point is that malfunctioning delivery vehicles (e.g., boosters that fail to ignite or defective guidance systems) would rarely deliver the warhead close enough to the intended target to create a local debris cloud and a serious fratricide risk.[37] As a result, U.S. war planners can assign a large number of warheads to each Russian target. If the delivery system for the first weapon functions properly, the target will likely be destroyed. If the first delivery vehicle malfunctions, it will probably not create a debris cloud over the target, and the next incoming warhead—if its delivery vehicle functions properly—can still succeed.

### ATTACK TIMING: CAN THE RUSSIANS LAUNCH UNDER ATTACK?

A critical issue for the outcome of a U.S. attack is the ability of Russia to launch on warning (i.e., quickly launch a retaliatory strike before its forces are destroyed). It is unlikely that Russia could do this. Russian commanders would need 7–13 minutes to carry out the technical steps involved in identifying a U.S. attack and launching their retaliatory forces. They would have to (1) confirm the sensor indications that an attack was under way; (2) convey the news to political leaders; (3) communicate launch authorization and launch codes to the nuclear forces; (4) execute launch sequences; and (5) allow the missiles to fly a safe distance from the silos.[38] This timeline does not include the time required by Russian leaders to absorb the news that a nuclear attack is

37. The fratricide problem is most severe for attacks against very hard targets because these attacks will produce the greatest proportion of "near misses" in which the target survives but there is a nearby debris cloud. Even against the hardest Russian targets, however, the problem of fratricide is small. For example, the attack simulated in this article targets the hardest Russian missile silos primarily with cruise missiles and SLBMs carrying W88 warheads. If the cruise missiles have a reliability of 80 percent and an accuracy of 30 meters CEP, each has a 79.999998 percent chance of destroying its target, a 20 percent chance of malfunctioning, and only a 0.000002 percent chance of functioning properly but delivering the warhead too far from the target to destroy it. Only in the latter case will the missile fail to destroy the target and create a serious fratricide risk. A larger fraction of the W88 warheads will be near misses (because the missiles that deliver them are less accurate than the cruise missiles), but the near misses would still be a small percentage of the total (1.4 percent). The fratricide risk will be at least an order of magnitude lower for attacks against softer targets. We thank Geoffrey Forden, George Lewis, and Theodore Postol for very helpful discussions about fratricide.

38. The sequence of steps and estimates of time requirements is from Postol, "The Nuclear Danger from Shortfalls in the Capabilities of Russian Early Warning Satellites." Postol's estimate is consistent with estimates of U.S. reaction time during the Cold War. See John D. Steinbruner, "Launch Under Attack," *Scientific American*, Vol. 250, No. 1 (January 1984), pp. 37–47.

under way and decide to authorize retaliation. Given that both Russian and U.S. early warning systems have had false alarms in the past, even a minimally prudent leader would need to think hard and ask tough questions before authorizing a catastrophic nuclear response.[39] Because the technical steps require 7–13 minutes, it is hard to imagine that Russia could detect an attack, decide to retaliate, and launch missiles in less than 10–15 minutes.

The Russian early warning system would probably not give Russia's leaders the time they need to retaliate; in fact it is questionable whether it would give them any warning at all. Stealthy B-2 bombers could likely penetrate Russian air defenses without detection. Furthermore, low-flying B-52 bombers could fire stealthy nuclear-armed cruise missiles from outside Russian airspace; these missiles—small, radar-absorbing, and flying at very low altitude—would likely provide no warning before detonation. Finally, Russia's vulnerability is compounded by the poor state of its early warning system. Russian satellites cannot reliably detect the launch of SLBMs; Russia relies on ground-based radar to detect those warheads.[40] But there is a large east-facing hole in Russia's radar network; Russian leaders might have no warning of an SLBM attack from the Pacific.[41] Even if Russia plugged the east-facing hole in its radar network, its leaders would still have less than 10 minutes' warning of a U.S. submarine attack from the Atlantic, and perhaps no time if the U.S. attack began with hundreds of stealthy cruise missiles and stealth bombers.[42]

### MODEL RESULTS

Table 4 presents the results of the modeled attack on Russian nuclear forces. The first row of results, the "base case," uses expected values for the accuracy and reliability of U.S. weapons and the hardness of Russian targets. In each row, the top number is the expected number of targets that survive; the bottom numbers reflect the range of targets that might survive (with a 95 percent confidence interval).

The model suggests that the Russian strategic nuclear force is extremely vulnerable. Using base-case values, zero Russian silo-based ICBMs, zero mobile missiles, zero bomber bases, and zero Russian SSBNs are expected to survive.

39. On early-warning false alarms, see Scott D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons* (Princeton, N.J.: Princeton University Press, 1993); and Podvig, "History and the Current Status of the Russian Early-Warning System," pp. 35, 40.
40. Podvig, "History and the Current Status of the Russian Early-Warning System"; and Postol, "The Nuclear Danger from Shortfalls in the Capabilities of Russian Early Warning Satellites."
41. Podvig, "History and the Current Status of the Russian Early-Warning System," pp. 31–32.
42. For maps of the holes in Russia's radar network, see Postol, "The Nuclear Danger from Shortfalls in the Capabilities of Russian Early Warning Satellites," pp. 37–38. More recent maps are available from the authors. China has even less ability to detect an incoming attack than Russia.

**Table 4. Model Results for U.S. Nuclear First Strike**

| Russian Target Type | Silo-Based ICBMs | Mobile ICBMs (in garrison) | Runways (9 key airfields) | Submarines (at port) |
|---|---|---|---|---|
| Before attack | 258 | 291 | 18 | 9 |
| After attack: base case<br>(95% confidence interval) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) |
| After attack: reduced accuracy<br>(95% confidence interval) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) |
| After attack: reduced reliability<br>(95% confidence interval) | 0<br>(0–1) | 0<br>(0–1) | 0<br>(0–1) | 0<br>(0–0) |
| After attack: stronger silos<br>(95% confidence interval) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) | 0<br>(0–0) |

NOTE: "Base case" is calculated using standard assumptions about U.S. warhead accuracy and reliability. In the "reduced accuracy" case, we reduced each U.S. weapon system's accuracy by 20 percent. In the "reduced reliability" case, we reduced the reliability rates for U.S. weapons from 80 percent to 70 percent. For the "stronger silos" case, we increased the hardness of Russian silos by 50 percent.

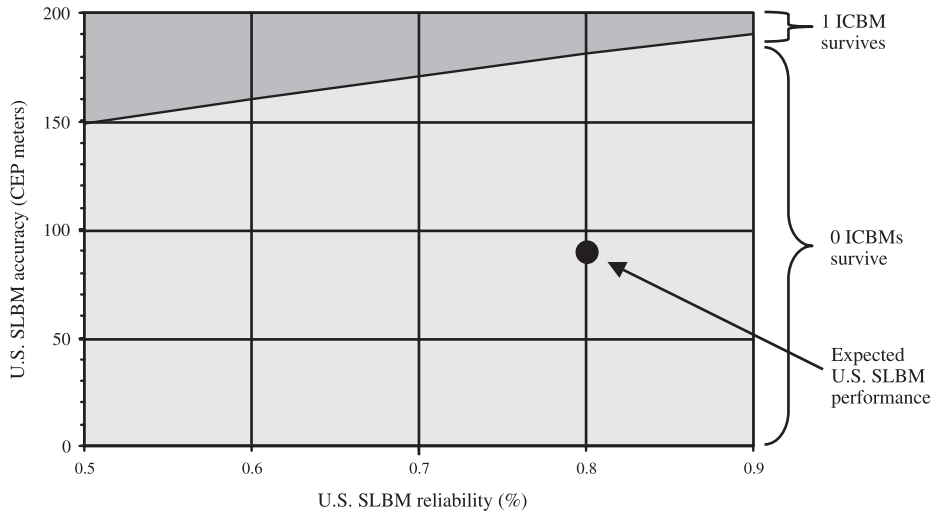
The range of plausible outcomes is even more striking: the likelihood of a single ICBM silo, mobile missile shelter, runway, or submarine surviving the attack falls outside the 95 percent confidence interval.

The other rows in Table 4 present the results of sensitivity analysis. The row below the base case indicates expected outcomes if the accuracy of all U.S. nuclear weapons is 20 percent worse than expected (i.e., CEP is increased by 20 percent). The next row shows the impact of reducing the reliability of U.S. weapons from 80 percent to 70 percent. The final row assumes that Russian ICBM silos are 50 percent harder than expected. None of these changes significantly reduces the vulnerability of the Russian nuclear force.

Figures 1 through 3 indicate the number of Russian ICBMs expected to survive if we simultaneously vary our estimates of U.S. accuracy and weapon reliability.[43] Figure 1 holds the performance of U.S. ICBMs and cruise missiles at expected levels and varies SLBM accuracy and reliability. The figure reveals that even major deviations from expected SLBM performance would not change the model results. This is particularly relevant because of the recent

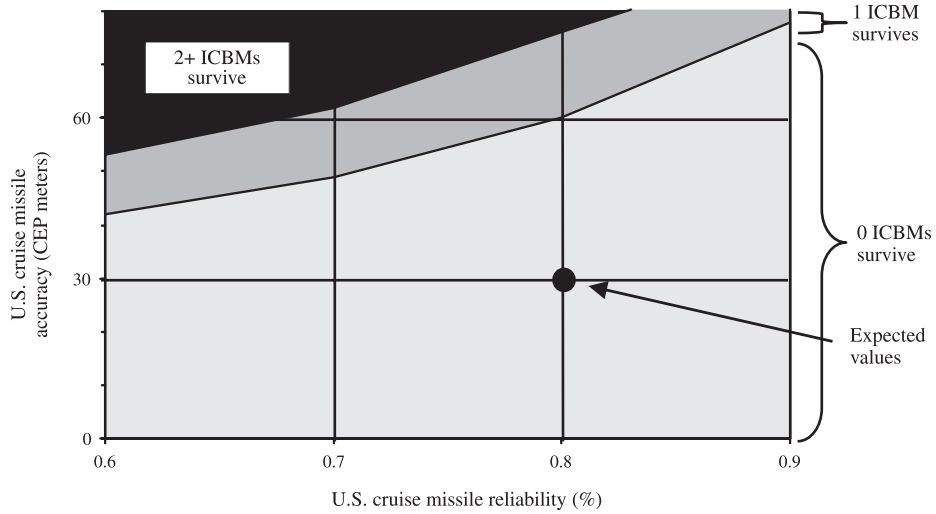
43. Figures 1–3 indicate only the number of Russian ICBMs that survive, not the total number of surviving Russian targets (i.e., ICBM silos, mobile missiles, runways, and submarines). We exclude other targets because summing the total number of surviving targets is deceptive. For example, there would probably be no adverse consequence to the United States if one Russian runway survived. But one surviving mobile ICBM might destroy a U.S. city, and one surviving submarine could destroy the United States.

**Figure 1. U.S. SLBM Performance and Russian ICBM Survivability**




NOTE: Assumes that U.S. ICBMs and cruise missiles function as expected.

**Figure 2. U.S. Cruise Missile Performance and Russian ICBM Survivability**




NOTE: Assumes that SLBMs and ICBMs perform as expected.

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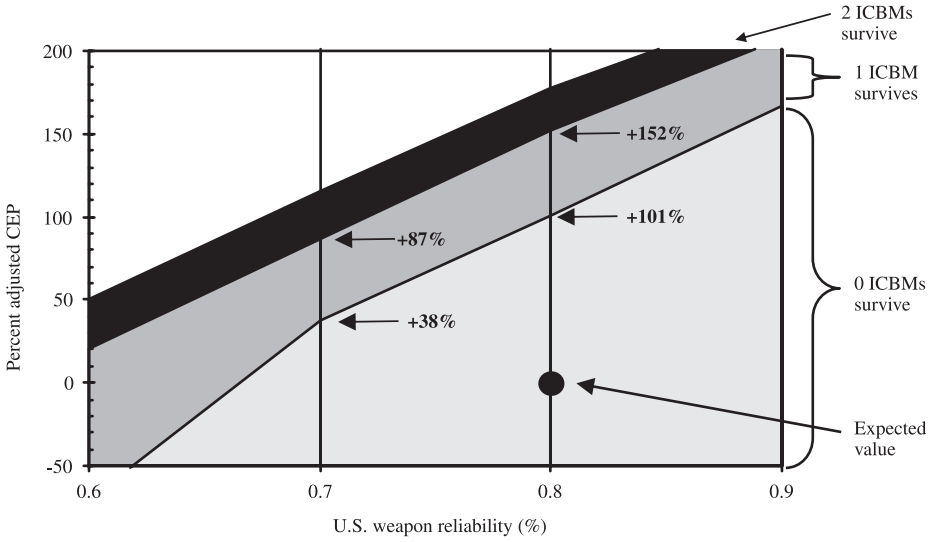
**Figure 3. Performance of U.S. Weapons and Russian ICBM Survivability**




controversy over the reliability of one type of U.S. SLBM warhead (see appendix 2).[44] Figure 2 shows similar results for cruise missile performance; even low reliability and bad accuracy would lead to the total destruction of the Russian force. Figure 3 demonstrates how outcomes differ as the reliability and accuracy of all U.S. weapon systems vary simultaneously. If U.S. weapons achieve expected reliability rates of 80 percent, all Russian ICBMs are destroyed unless the accuracy of the average weapon is 101 percent worse than expected; if reliability is 70 percent across the board, all Russian ICBMs are still destroyed unless U.S. accuracy is 38 percent worse than expected.

U.S. and Russian leaders should interpret the results of the model differently. The findings should not convince U.S. leaders that the United States has a reliable counterforce option against Russia. Many uncertainties are not captured in our model. For example, a U.S. submarine commander might not receive, or might not believe, his launch orders. Furthermore, this plan would require complex timing to avoid warhead fratricide.[45] But despite these uncer-

44. Some critics suggest that the navy's W76 warhead is not reliable. Appendix 2 rebuts this claim using data on W76 tests and argues that the warhead is highly reliable. Nevertheless, Figure 1 demonstrates the robustness of our findings for a wide range of SLBM and warhead reliability rates.

45. On the sources of uncertainty in a nuclear first strike, see Steinbruner and Garwin, "Strategic Vulnerability"; Alexander Cockburn and Andrew Cockburn, "The Myth of Missile Accuracy,"

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tainties, Russian (and Chinese) military planners should view these results with grave concern. Nuclear deterrence should not rest on the hope that the enemy's weapons perform far below expectations or that the enemy's submarine commanders will not receive or follow orders. The potential of a U.S. first strike to destroy a large arsenal such as Russia's is a stunning change in the strategic nuclear balance.

## *Capability Trends and New Initiatives*

Our model demonstrates that the United States already has considerable first-strike capabilities. Based on current trends, U.S. nuclear advantages will grow in coming years. Russian forces will continue to erode, and Chinese nuclear modernization will progress slowly. In contrast, the United States is pursuing a range of initiatives that will greatly increase the lethality of its arsenal.

### THE RUSSIAN AND CHINESE NUCLEAR ARSENALS: EROSION AND STASIS

The erosion of Russia's nuclear capabilities is likely to continue, thereby reducing the counterforce requirements for a U.S. first strike. Officials previously announced plans to reduce Russia's arsenal to 1,500 warheads by 2012, but actual reductions will likely be steeper. More than 80 percent of Russia's silo-based ICBMs have exceeded their original service lives; failed tests and low rates of production have stymied plans to replace them with new missiles. Similarly, Russia intends to keep retiring its aging mobile ICBMs and replacing them with new mobile missiles, but production of the new missiles continues to fall further behind schedule. The fast pace of missile retirements and slow pace of production could leave Russia with as few as 150 land-based missiles by the year 2010, down from nearly 550 today and almost 1,300 missiles in 1990.[46]

Russia's ballistic missile submarine force faces a similar fate. Six SSBNs are expected to be retired in the next few years; they are scheduled to be replaced by 5 submarines: 4 existing boats that are currently being overhauled and one new SSBN.[47] Therefore, even if Russia's plans for its fleet are realized, the submarine force will initially shrink from 9 submarines to 8. But Russia's planned submarine deployments are unlikely to occur on schedule. Work on the sub-

*New York Review of Books*, November 20, 1980, pp. 40–44; and Bunn and Tsipis, "The Uncertainties of Preemptive Nuclear Attack."

46. Pavel Podvig, "Russian Strategic Nuclear Forces in the Next Decade," Aspen Institute Italia, News Analysis Series, Vol. 3 (January 2005); Podvig, "Current Status of the Strategic Forces"; and Norris and Kristensen, "Russian Nuclear Forces, 2006."

47. Podvig, "Current Status of the Strategic Forces"; and Podvig, "Russian Strategic Nuclear Forces in the Next Decade."

marines in overhaul has repeatedly been delayed, and the new Russian SSBN will remain unarmed until the new missile it is designed to carry becomes available; however, although the missile was recently flight-tested, its production schedule has slipped to 2008 at the earliest.[48] Even worse from the perspective of stable deterrence, tight budgets and deteriorating performance continue to curtail the frequency of Russian submarine patrols.[49]

China's ability to redress the nuclear imbalance is even more suspect. Much has been made of China's ongoing defense modernization, but the country's strategic arsenal is growing at a glacial pace. China has only 18 ICBMs, a number that has remained essentially unchanged for more than a decade. In addition, these missiles are kept unfueled, and their warheads are stored separately. U.S. intelligence predicts that China will eventually deploy a new generation of ICBMs—modern mobile missiles—and field as many as 100 by 2020. This is certainly possible, but analysts have been expecting this deployment since the mid-1980s. According to unclassified reports, U.S. intelligence analyses repeatedly forecast the imminent deployment of advanced Chinese mobile ICBMs because they based their estimates on calculations of what China could conceivably do, rather than on concrete evidence of missile production.[50] Beyond its small ICBM force, China deployed 1 SSBN in 1983, but it had such poor capabilities that it never left Chinese waters and is no longer operational. China is designing a new class of SSBNs, but progress has been slow; even the U.S. Defense Department estimates that operational deployment is many years away.[51]

### THE U.S. NUCLEAR FORCE: MISSILE DEFENSE AND NEW INITIATIVES

While the Russian force erodes and the Chinese arsenal barely improves, the United States is significantly enhancing its strategic nuclear capabilities. The 2001 *Nuclear Posture Review* issued by George W. Bush's administration reaffirms the importance of nuclear weapons in U.S. national security strategy and endorses a set of programs that will greatly increase the offensive power of the U.S. nuclear arsenal.

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48. Norris and Kristensen, "Russian Nuclear Forces, 2006," pp. 66–67; Podvig, "Borey Submarine Launch Postponed until 2007"; Pavel Podvig, "Successful Launch of a Bulava Missile," http://www.globalsecurity.org/wmd/systems/index.html; and "Bulava Flight Tests Slip to 2008," in *Jane's Missiles and Rockets* (Surrey, U.K.: Jane's Information Group, April 2005).
49. Kristensen, "Russian Nuclear Submarine Patrols"; Norris and Kristensen, "Russian Nuclear Forces, 2004"; and Blair and Gaddy, "Russia's Aging War Machine."
50. Jeffrey Lewis, "The Ambiguous Arsenal," *Bulletin of the Atomic Scientists*, Vol. 61, No. 3 (May/June 2005), p. 57.
51. Lewis, "The Ambiguous Arsenal"; and Robert S. Norris and Hans M. Kristensen, "Chinese Nuclear Forces, 2003," *Bulletin of the Atomic Scientists*, Vol. 59, No. 6 (November/December 2003), pp. 77–80.

MISSILE DEFENSE. U.S. offensive nuclear capabilities will grow as the United States deploys a national missile defense (NMD) system. In 2001 the United States withdrew from the Antiballistic Missile Treaty and began to build a missile shield. The first contingent of NMD interceptors was deployed in 2004, but this step is only the starting point for a large, multilayered missile defense system. To this end, the United States has doubled investment in missile defense and accelerated research and development on a range of land-, air-, sea-, and space-based missile defense systems.[52]

Opponents of national missile defense raise two important critiques regarding its feasibility. First, they note that even a few hundred incoming warheads would overwhelm any plausible defense. Second, a missile defense system based on intercepting warheads outside the Earth's atmosphere is impractical because it is extremely difficult to differentiate decoys from warheads in space.[53] Although both criticisms are cogent, even a limited missile shield could be a powerful complement to the offensive capabilities of U.S. nuclear forces. Russia has approximately 3,500 strategic nuclear warheads today, but if the United States struck before Russian forces were alerted, Russia would be lucky if a half-dozen warheads survived. A functioning missile defense system could conceivably destroy six warheads. Furthermore, the problem of differentiating warheads from decoys becomes less important if only a handful of surviving enemy warheads and decoys are left to intercept. Facing a small number of incoming warheads and decoys, U.S. interceptors could simply target them all.

OFFENSIVE STRIKE SYSTEMS. The United States plans to reduce the size of its nuclear force over the next decade, but it will increase the counterforce capabilities of that arsenal. Although efforts to build new low-yield warheads and earth-penetrating weapons have attracted more attention, a significant leap in U.S. nuclear capability will result from planned improvements to the United States' SLBM and ICBM arsenal. Navy officials are exploring ways to significantly improve the accuracy of some of its highly accurate Trident II SLBMs

52. White House, "Administration Missile Defense Papers," July 2001, http://www.ceip.org/files/projects/npp/resources/embassycablenmd.htm; White House, "President Announces Progress in Missile Defense Capabilities," December 17, 2002, http://www.whitehouse.gov/news/releases/2002/12/20021217.html; White House, "National Policy on Ballistic Missile Defense Fact Sheet," May 20, 2003, http://www.whitehouse.gov/news/releases/2003/05/20030520-14.html; and Missile Defense Agency, U.S. Department of Defense, "MDALink," 2005, http://www.mda.mil/mdalink/html/mdalink.html.

53. George N. Lewis, Theodore A. Postol, and John Pike, "Why National Missile Defense Won't Work," *Scientific American*, Vol. 281 (August 1999), pp. 36–41; and Lisbeth Gronlund, David C. Wright, George N. Lewis, and Philip E. Coyle III, *Technical Realities: An Analysis of the 2004 Deployment of a U.S. National Missile Defense System* (Washington, D.C.: Union of Concerned Scientists, 2004).

by making the reentry vehicles maneuverable and giving them Global Positioning Satellite receivers. They expect that missile accuracy could improve from the current figure of 90 meters to 12 meters or less.[54] In addition, the navy plans to replace the fuse for the warheads on almost half of these missiles to allow them to detonate at ground level; currently they can only be set for an airburst, which is not ideal for attacking very hard targets. The combined effect of these improvements—substantially increased accuracy and a ground-burst fuse—will greatly increase the lethality of the U.S. submarine force against very hard targets such as missile silos.[55] The United States is also planning to upgrade its ICBM force. It will take reentry vehicles and warheads from retired MX missiles and use them to upgrade approximately 200 Minuteman ICBMs. The upgrade will improve the ICBM's accuracy and nearly double its warhead yield.

The United States is also improving a slew of nonnuclear capabilities that will increase its ability to destroy an enemy's nuclear arsenal. For example, the United States continues to work on locating very quiet SSBNs, reportedly continuing to send attack submarines into Russian waters to try to track Russian submarines.[56] Other initiatives seek to improve the U.S. ability to find mobile missile launchers and to deploy ground- and space-based systems that could destroy or disable enemy satellites.[57] The former capability appears aimed at a future in which an adversary has a dispersed mobile ICBM force (as China is allegedly building); antisatellite weapons would be useful if future adversaries develop reliable satellite early-warning systems to detect an incoming nuclear attack.

### THE INTENTIONAL PURSUIT OF NUCLEAR PRIMACY?

One might argue that the various new U.S. initiatives discussed above do not reflect the deliberate pursuit of nuclear primacy, but rather the need to counter threats posed by terrorists or rogue states. Several of the programs may indeed be aimed at rogue states; for example, missile defense may be envisioned as a means to protect the United States from a future Iranian or North Korean

54. Norris and Kristensen, "U.S. Nuclear Forces, 2005," *Bulletin of the Atomic Scientists*, Vol. 61, No. 1 (January/February 2005), pp. 73–75; and Norris and Kristensen, "U.S. Nuclear Forces, 2006."
55. Norris and Kristensen, "U.S. Nuclear Forces, 2006"; and Bob Aldridge, "U.S. Trident Submarine and Missile System: The Ultimate First-Strike Weapon" (Santa Clara, Calif.: Pacific Life Research Center, November 16, 2002), pp. 6–7.
56. Massachusetts Institute of Technology, "The Future of Russian-U.S. Arms Reductions: START III and Beyond," summary of conference proceedings, February 2–6, 1998; and personal communciation with Kristensen.
57. Tim Weiner, "Air Force Seeks Bush's Approval for Space Arms," *New York Times*, May 18, 2005; and Department of Defense, *Nuclear Posture Review [Excerpts]*, January 8, 2002, http://www.globalsecurity.org/wmd/library/policy/dod/npr.htm.

ICBM. Similarly, North Korea and Iran have mobile launchers for nonnuclear short-range missiles; an ability to locate and destroy them would be helpful in a future war.

Other U.S. nuclear programs are hard to explain with any mission other than a nuclear first strike on a major power adversary. For example, the decision to upgrade the fuse of many SLBM warheads (the W76s) to permit ground bursts makes sense only if the mission is destroying hundreds of hardened silos. One might argue that ground bursts could be useful for a variety of other missions, such as destroying North Korean WMD bunkers or remote cave complexes housing terrorist leaders. The United States, however, already has a large number of highly accurate, similar-yield warheads that would be ideal for these purposes.[58] Upgrading the W76 warheads is difficult to justify unless the United States is pursuing nuclear primacy, and therefore needs the ability to destroy hundreds of hardened enemy silos. Similarly, efforts to refine U.S. SLBM accuracy are irrelevant unless the missiles are aimed at very hard targets such as missile silos. Against other targets, it makes no difference whether the 100-kiloton warhead detonates 30 or 90 meters away.[59]

The United States' efforts to improve its antisubmarine warfare capabilities are understandable because regional adversaries—and China—have quiet diesel submarines. However, aggressive efforts to track Russia's nuclear-powered SSBNs—indicated by continued U.S. attack submarine operations in Russian waters—suggest the pursuit of nuclear primacy.

Other analysts have noted that the current U.S. nuclear force looks surprisingly like an arsenal designed for a nuclear first strike against Russia or China. "The U.S. arsenal today looks much as it would if a disarming strike against Russia were still its dominant mission," a scholar at the Federation of American Scientists writes.[60] A group of RAND analysts agrees: "What the planned force appears best suited to provide beyond the needs of traditional deterrence

58. The United States has 1,400 nuclear-armed cruise missiles with adjustable-yield warheads that could detonate at the W76's yield and exceed the W76's current accuracy. The United States also has 384 W88 warheads on SLBMs that can be used for ground bursts, though at a much higher yield than the W76.

59. The "deterrent" mission—threatening retaliatory strikes on an enemy's cities if it launches a nuclear attack on the United States—requires no increase in U.S. missile accuracy. The smaller of the two types of warhead on U.S. SLBMs (100 kiloton) would start mass fires well beyond 4,000 meters from detonation. See Glenn C. Buchan, David Matonick, Calvin Shipbaugh, and Richard Mesic, *Future Roles of U.S. Nuclear Forces: Implications for U.S. Strategy*, MR-1231AF (Santa Monica, Calif.: RAND, 2003), pp. 52–54. For the purpose of destroying cities, it therefore makes no difference if the warhead is delivered 30 meters or 90 meters from the intended target. See also Lynn Eden, *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* (Ithaca, N.Y.: Cornell University Press, 2003).

60. Ivan Oelrich, "Missions for Nuclear Weapons after the Cold War," Occasional Paper No. 3 (Washington, D.C.: Federation of American Scientists, January 2005), p. 41.

is a *preemptive counterforce capability against Russia and China*. Otherwise, the numbers and the operating procedures simply do not add up."[61] These analysts appear to believe that the steadily growing U.S. counterforce capability reflects something akin to bureaucratic momentum, not a desire to achieve first-strike capability. Although the tendency of weapons designers and military organizations to constantly seek to improve their forces is well documented,[62] the steady improvement in the U.S. nuclear arsenal is entirely consistent with America's across-the-board effort to maintain and expand its military primacy.[63]

The United States is openly seeking primacy in every other dimension of modern military technology. The desire to modernize U.S. conventional forces is broadly and correctly interpreted as an effort to build the tools necessary to retain U.S. military supremacy. The simultaneous modernization of U.S. nuclear weapon systems should be seen in the same light.

## *Implications and Counterarguments*

The shift in the nuclear balance could significantly damage relations among the great powers and increase the probability of nuclear war. First, the United States' growing offensive nuclear capabilities will pressure Russia and China to reduce the peacetime vulnerability of their forces. The steps that they may take to do this—for example, building larger nuclear arsenals, dispersing nuclear forces, predelegating launch authority to local commanders, and adopting a hair-trigger nuclear retaliatory doctrine—may signal the beginning of an intense, new nuclear arms race. Even worse, these steps may increase the danger of nuclear accidents, including unauthorized and accidental nuclear war.[64] In the past, both U.S. and Russian early warning systems have sounded false

61. Buchan et al., *Future Roles of U.S. Nuclear Forces*, p. 92 (emphasis in original).
62. See, for example, Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, Mass.: MIT Press, 1990).
63. Skeptics may wonder whether the United States' continued moratorium on nuclear testing demonstrates that the U.S. government does not seek nuclear primacy. We thank Stephen Rosen for bringing this argument to our attention. The need for additional testing, however, is much weaker if U.S. decisionmakers are confident about the reliability of U.S. warheads. Our analysis in appendix 2 suggests that U.S. leaders should have considerable faith in U.S. warhead reliability.
64. A Russian launch-on-warning doctrine would not eliminate Russia's vulnerability because the holes in its warning system and the capabilities of the United States' stealthy nuclear cruise missiles mean that it is unlikely that Russia could detect and respond to an attack before the first wave of warheads arrived. Nevertheless, prudent Russian military planners may (correctly) view launch-on-warning as one step that would complicate U.S. nuclear war plans, requiring an even more precisely timed and coordinated first strike. China, on the other hand, cannot adopt a launch-on-warning doctrine because it has a rudimentary early warning capability and because its ICBMs are kept unfueled and without warheads.

alarms of incoming nuclear attacks; this record suggests that the dangers associated with accidental nuclear war are serious.[65]

The second implication of the United States' emerging nuclear primacy is that it may trigger dangerous dynamics during crises and wars. If Russia and China do not sufficiently reduce their peacetime vulnerability, they will feel compelled to do so if they find themselves in a crisis with the United States. Efforts to ready and disperse nuclear forces during a crisis, however, can be perilous, especially once conventional military operations begin. For example, a Chinese nuclear alert during a Sino-U.S. war over Taiwan might appear to U.S. leaders that China was preparing to use nuclear weapons.[66] Under these circumstances, U.S. leaders would face great pressure to preempt a potential Chinese attack rather than wait and see if China strikes nearby U.S. military forces, a U.S. ally, or (less likely) the American homeland. (U.S. leaders are well aware of repeated comments by Chinese military officers suggesting that China might use nuclear weapons to destroy American cities if the United States supported Taiwan in a war for independence.[67]) In a similar vein, during a conventional war over Taiwan, U.S. military forces would likely attack Chinese air defense radars, communications hubs, military command and control sites, mobile missile launchers, and submarines. These attacks—designed to win the conventional war—would be indistinguishable to China's leaders from the steps the United States might take prior to attacks on China's small strategic nuclear force. Facing a possible nuclear strike, China might alert its nuclear forces or even initiate regional nuclear war to deter further U.S. nuclear escalation.[68]

Third, if Russia and China do not adequately reduce the vulnerability of their nuclear forces, U.S. leaders will soon have the option of launching a disarming attack against either country. Some analysts consider this scenario unthinkable: it would, after all, entail enormous risks and horrifying costs. History and current policy trends suggest, however, that the possibility of a U.S. nuclear attack should not be entirely dismissed. Nuclear counterforce was the cornerstone of American national security strategy during the previous era

65. During periods of the Cold War, the United States and the Soviet Union adopted launch-on-warning retaliatory doctrines to reduce the vulnerability of land-based nuclear forces. On at least four occasions (three during the Cold War and one since), early warning systems indicated that a nuclear attack was incoming.

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66. For example, as part of the Chinese alert, ICBMs might be fueled; warheads could be moved to the site of missiles; and party leaders in Beijing could be dispersed.

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67. Most recently, see Joseph Kahn, "Chinese General Threatens Use of A-Bombs if U.S. Intrudes," *New York Times*, July 15, 2005.

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68. On the escalatory dangers that would arise from normal conventional combat operations, see Posen, *Inadvertent Escalation*.

of U.S. nuclear primacy (the early 1950s until the early 1960s). During this period, U.S. leaders planned to launch a massive nuclear attack on the Soviet Union, Eastern Europe, and China if the Soviets launched a conventional attack on Europe.[69] Indeed, in 1961, at the peak of the Berlin crisis, U.S. leaders modified war plans to improve the odds that a disarming strike on the Soviet Union would succeed, and President John Kennedy carefully explored the option of initiating such a surprise nuclear attack.[70] Moreover, both the United States and the Soviet Union considered launching attacks on China to prevent its ascension to the nuclear club.[71] In a new era of U.S. nuclear primacy, U.S. policymakers may once again be tempted to consider nuclear escalation during intense crises or if nonnuclear military operations go unexpectedly badly for the United States (e.g., in Korea).[72]

Critics of this analysis may raise several counterarguments. First, the dan-

69. U.S. nuclear policy during this period became publicly known as "massive retaliation," but the strategy was more accurately one of massive preemption. Given warning of hostilities—with "warning" never formally defined—U.S. war plans called for a full-scale nuclear attack against all categories of targets (nuclear capabilities, military forces, and urban-industrial targets) within the entire Communist bloc. David Alan Rosenberg, "'A Smoking Radiating Ruin at the End of Two Hours': Documents on American Plans for Nuclear War with the Soviet Union, 1954–55," *International Security*, Vol. 6, No. 3 (Winter 1981/82), pp. 3–38; David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons and American Strategy, 1945–1960," *International Security*, Vol. 7, No. 4 (Spring 1983), pp. 3–71; and Scott D. Sagan, "SIOP-62: The Nuclear War Plan Briefing to President Kennedy," *International Security*, Vol. 12, No. 1 (Summer 1987), pp. 22–51.

70. Trachtenberg, *A Constructed Peace*, pp. 289–297; Fred Kaplan, "JFK's First-Strike Plan," *Atlantic Monthly*, Vol. 288, No. 3 (October 2001), pp. 81–86; and William Burr, "First Strike Options and the Berlin Crisis, September 1961: New Documents from the Kennedy Administration," National Security Archive Electronic Briefing Book, No. 56 (Washington, D.C.: National Security Archive, 2001).

71. William Burr and Jeffrey T. Richelson, "Whether to 'Strangle the Baby in the Cradle': The United States and the Chinese Nuclear Program, 1960–64," *International Security*, Vol. 25, No. 3 (Winter 2000/01), pp. 54–99.

72. The United States is not likely to place the same reliance on nuclear threats during this coming period of nuclear primacy as it did in the 1950s. One reason is clear: today the United States also enjoys a substantial lead in conventional military power over plausible adversaries. The lessons of the past suggest, however, that the United States may use nuclear threats—or be tempted to launch disarming strikes—in intense crises if conventional options appear costly or unlikely to succeed. In fact, as many critics note, current U.S. doctrine affirms the preemptive use of nuclear weapons against any adversary armed with weapons of mass destruction. Department of Defense, *Nuclear Posture Review [Excerpts]*; George W. Bush, *The National Security Strategy of the United States of America*, September 2002, http://www.state.gov/documents/organization/15538.pdf; White House, *National Strategy to Combat Weapons of Mass Destruction*, December 2002, http://www.state.gov/documents/organization/16092.pdf; Joint Chiefs of Staff, *Doctrine for Joint Nuclear Operations [Draft]*, March 15, 2005, http://www.nukestrat.com/us/jcs/JCS_JP3-12_05draft.pdf; Hans M. Kristensen, "The Role of U.S. Nuclear Weapons: New Doctrine Falls Short of Bush Pledge," *Arms Control Today*, Vol. 35, No. 7 (September 2005), pp. 13–19; William M. Arkin, "Secret Plan Outlines the Unthinkable," *Los Angeles Times*, March 9, 2002; Mike Allen and Barton Gellman, "Preemptive Strikes Part of U.S. Strategic Doctrine," *Washington Post*, December 11, 2002; William M. Arkin, "Not Just a Last Resort?" *Washington Post*, May 15, 2005; and Walter Pincus, "Pentagon Revises Nuclear Strike Plan," *Washington Post*, September 11, 2005.

gers of nuclear imbalance may be exaggerated, because the era of U.S. primacy may be brief. According to this argument, Russian (and perhaps Chinese) leaders can take simple steps to ensure the survivability of their nuclear forces—and can do so without adopting destabilizing nuclear doctrines or force postures. For example, Russia could keep 50 mobile missiles on continuous peacetime alert or substantially increase its nuclear submarine patrols. Either step would dramatically reduce Russia's vulnerability. Moreover, these steps would occur rapidly if relations between the United States and Russia significantly worsened.

Russia and perhaps China can take steps to reduce their vulnerability—and we believe they eventually will—but maintaining a survivable retaliatory force will grow increasingly difficult. Russia's mobile SS-25 missiles are at the end of their service lives and are being retired, while its new mobile SS-27 missile system is deploying very slowly. Even assuming that recurrent test delays, production problems, and funding shortfalls can be overcome, Russia is expected to add only 3 mobile SS-27s annually, with perhaps 20–25 additional mobile missiles operational by 2015.[73] Likewise, as Russian submarines spend more and more time pier side, the skills needed to carry out future deterrent patrols will erode, as will the ability of Russian submarine crews to evade U.S. attack submarines that seek out and trail Russian patrols.[74]

Furthermore, Russian efforts to reestablish a secure retaliatory capability must contend not only with the forces currently in the U.S. arsenal but also with the capabilities that are being developed. The effort to roll back U.S. nuclear primacy must now contend with a United States that is working hard to exploit the revolution in military affairs to enhance its nuclear forces. For example, the United States' emerging first-strike capability is being bolstered by huge improvements in accuracy, wide-area remote sensing (directed at finding relocatable targets such as mobile ICBMs), and antisubmarine warfare.[75] A series of U.S. initiatives aimed at deploying offensive and defensive weapons in space, if approved, will widen the capability gap between the United States and other nuclear powers.[76] In addition to these projects that are in the ad-

73. Pavel Podvig, "Serious (but Expected) Cuts in the Missile Force," April 1, 2005, http://russianforces.org/eng/blog/archive/000496.shtml; Pavel Podvig, "START Data Reflect Changes in the Russian Strategic Forces, April 4, 2005, http://russianforces.org/eng/news/archive/000500.shtml; and Norris and Kristensen, "Russian Nuclear Forces, 2006," pp. 65–66.

74. Kristensen, "Russian Nuclear Submarine Patrols."

75. Many of these ongoing and planned improvements are discussed in Department of Defense, *Nuclear Posture Review [Excerpts]*.

76. For example, the Pentagon's Global Strike program, which involves deploying space planes that are capable of precisely striking targets (with a CEP less than 3 meters) anywhere in the world within 45 minutes, would give the United States an unprecedented ability to destroy strategic forces (i.e., nuclear ballistic missiles), command and control facilities, and long-range air defenses.

vanced stages of planning, the U.S. Air Force recently launched a new microsatellite specifically designed to disrupt other states' military reconnaissance and communication satellites.[77] Russia and China will face tremendous pressure to respond to these and other technological advances. Doing so, however, will require a substantial investment of resources and sustained commitment to the complex business of strategic nuclear deterrence.

A second critique of our analysis could arise from the "nuclear taboo" literature. According to this view, nuclear weapons are so abhorrent that their use by U.S. decisionmakers is practically unthinkable.[78] U.S. leaders would never seriously consider launching a preventive nuclear attack, so the emergence of U.S. nuclear primacy is at worst a waste of tax dollars. From a strategic standpoint, such primacy is largely irrelevant.

We offer three responses to this argument. First, even if the claims about the nuclear taboo are correct, they merely mitigate one of the dangerous consequences of U.S. nuclear primacy: the temptation for preventive U.S. nuclear attacks. The taboo argument is that leaders will be highly reluctant to use their nuclear weapons—not that they will trust others to refrain from resorting to nuclear war. In fact, the period of the alleged nuclear taboo—from the mid-1960s to the present[79]—encompasses the decades in which the United States and the Soviet Union went to their greatest lengths to protect their nuclear arsenals from disarming attacks; they were both clearly afraid of an enemy nuclear strike. Thus, even if the taboo argument were correct, there is little reason to believe that it will dissuade Russia and China from undertaking strenuous efforts to mitigate their growing nuclear vulnerability, thereby inadvertently increasing the danger of nuclear accidents, arms racing, and crisis instability.

Second, there are good evidentiary reasons for questioning the strength of the nuclear taboo. A leading scholar of the taboo, Nina Tannenwald, argues that it had become institutionalized within the U.S. government by the beginning of the 1960s and was reflected in the policies of the Kennedy administration. Tannenwald argues that President Kennedy and Secretary of Defense Robert McNamara found the idea of using nuclear weapons largely "unthink-

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Rods from God, a new initiative that evolved from a 1980s' plan, would consist of orbiting platforms stocked with huge metal rods that would be launched and satellite-guided to destroy targets anywhere on Earth within minutes. According to official doctrine, the primary targets of Rods from God would be hardened missile silos or enemy satellite systems. Tim Weiner, "Air Force Seeks Bush's Approval for Space Arms," *New York Times*, May 18, 2005; and Giuseppe Anzera, "The Pentagon's Bid to Militarize Space," *Power and Interest News Report*, August 17, 2005.

77. Weiner, "Air Force Seeks Bush's Approval for Space Arms."

78. See Tannenwald, "Stigmatizing the Bomb"; and Nina Tannenwald, "The Nuclear Taboo: The United States and the Normative Basis of Nuclear Nonuse," *International Organization*, Vol. 53, No. 3 (Summer 1999), pp. 433–468.

79. Tannenwald, "Stigmatizing the Bomb."

able." She cites McNamara's claims in his memoirs that he "would never advise the president to use nuclear weapons first."[80] Newly declassified documents, however, reveal discrepancies between the views that McNamara and others held during the 1960s and the views they later professed in their memoirs. For example, in 1963 McNamara and Kennedy discussed U.S. options if China attacked India for a second time. In audio recordings, McNamara is heard to say, "Before any substantial commitment to defend India against China is given, we should recognize that in order to carry out that commitment against any substantial Chinese attack, we would have to use nuclear weapons. Any large Chinese Communist attack on any part of that area would require the use of nuclear weapons by the U.S., and this is to be preferred over the introduction of large numbers of U.S. soldiers." But rather than shrink back from the prospect of using nuclear weapons, Kennedy replied, "We should defend India, and therefore we will defend India" if attacked.[81] One might argue that these were merely policy discussions and did not, after all, reflect actual behavior, but it is difficult to see a nuclear taboo permeating these deliberations.

Other evidence from the Kennedy administration also casts doubt on the strength of the nuclear taboo. For example, at the peak of the Berlin crisis of 1961, senior civilians in the White House worked with the Joint Chiefs of Staff to modify U.S. nuclear war plans to improve the chances of a successful first strike.[82] This was not merely the work of midlevel bureaucrats. Their work led President Kennedy himself to notify the Joint Chiefs of Staff in September 1961 that he wanted a briefing the next day on the U.S. military's ability to launch a surprise nuclear disarming strike on the Soviet Union. Far from being a purely hypothetical interest, Kennedy's message to the Joint Chiefs said that he wanted this information immediately because "Berlin developments may confront us with a situation where we may desire to take the initiative in the escalation of conflict from the local to the general war level."[83] "General war" was a euphemism for nuclear war.

Moreover, even scholars who argue that there is a powerful taboo agree that

80. Ibid., pp. 27–31, at p. 30.
81. Anand Giridharadas, "'63 Tapes Reveal Kennedy and Aides Discussed Using Nuclear Arms in a China-India Clash," *New York Times*, August 26, 2005.
82. President Kennedy was deeply interested in the preemptive war option: he repeatedly discussed the issue with top political and military leaders; pressed hard for reports on the mechanics and effectiveness of a nuclear first strike, especially if the Berlin crisis were to escalate into armed conflict; and concluded that a preemptive strike was a viable policy option. Trachtenberg, *A Constructed Peace*, pp. 289–297; and Kaplan, "JFK's First-Strike Plan," pp. 81–86.
83. "Memorandum to General Lemnitzer," September 19, 1961, in Burr, "First Strike Options and the Berlin Crisis."

nuclear weapons may be used in high-stakes crises. The central claim about the nuclear taboo is that it inhibits the use of nuclear weapons but does not prevent it. The implication is that in future high-stakes crises, U.S. leaders may consider initiating nuclear war just as they did in the past. And to avoid such circumstances, U.S. adversaries will work hard to mitigate their vulnerability. Some scholars of the nuclear taboo appear to agree with our analysis on this point, worrying that the statements, discourse, and actual nuclear weapons policies emerging from the George W. Bush administration could seriously weaken the nuclear taboo.[84] As Tannenwald writes, the nuclear taboo would be especially damaged "if the nuclear doctrines of nuclear states continue to emphasize nuclear weapons as an important instrument of national security and even develop new roles for them"; if we see the "development of new generations of 'mini-nukes' that blur the line between conventional and nuclear weapons, thus lowering the threshold for nuclear use"; or if the United States continues with "loose talk about the potential utility of nuclear weapons."[85] Tannenwald remains hopeful that both strategic and normative factors will mitigate against these developments, but others are less optimistic that the Bush administration will shift course in its nuclear policy or discourse.[86]

A third counterargument posits that deterrence will remain robust even if some nuclear arsenals are now highly vulnerable. According to this view, nuclear deterrence does not hinge on assured retaliation; merely the possibility of retaliation will deter potential attackers because the consequences of retaliation would be so terrible. All that is required for stable nuclear deterrence is, therefore, first-strike uncertainty, and the outcome of war is always uncertain.[87] The implication is that U.S. adversaries will not take destabilizing steps

84. For example, the 2001 *Nuclear Posture Review* and subsequent official documents emphasize that nuclear weapons are a core instrument of U.S. national security policy. These documents explicitly reject the idea that nuclear weapons can be used only in retaliation after an adversary's nuclear attack; they call for new types of nuclear weapons for new strategic missions; and they tighten the integration of nuclear forces into conventional war plans. Department of Defense, *Nuclear Posture Review [Excerpts].*

85. Tannenwald, "Stigmatizing the Bomb," p. 43.

86. See Hans M. Kristensen, "Doctrine for Joint Nuclear Operations, Fall 2005," http://www.nukestrat.com/us/jcs/jp3-12_05.htm; Kristensen, "The Role of U.S. Nuclear Weapons"; and William M. Arkin, "The Real Nuclear Option on the Hill," *Washington Post*, October 13, 2005.

87. A strong case for this position is made in Avery Goldstein, *Deterrence and Security in the Twenty-first Century: China, Britain, France, and the Enduring Legacy of the Nuclear Revolution* (Stanford, Calif.: Stanford University Press, 200), pp. 42–46; and Devin T. Hagerty, *The Consequences of Nuclear Proliferation: Lessons from South Asia* (Cambridge, Mass.: MIT Press, 1998), p. 26. These critics are positing a theory of nuclear deterrence that differs from the mainstream Cold War view that emphasized the need for "assured destruction," and also from the view of Cold War critics who advocated "minimal deterrence." The "massive assured destruction" view holds that stable deterrence requires the assurance that any attack would trigger a massive retaliatory response. The "minimal deterrence" view posits that stable deterrence merely requires the assurance that any at-

to reverse their growing vulnerability, and the U.S. leadership will not be tempted to launch preventive attacks.

These critics are only half right: there is no deductive reason to believe that stable deterrence requires that retaliation be assured; some probability of nuclear retaliation far below 100 percent should deter almost any prospective attacker. They err, however, in assuming that any level of first-strike uncertainty will create a powerful deterrent effect. There is no deductive reason to believe that a country with a 95 percent chance of successfully destroying its enemy's nuclear force on the ground will act as cautiously as a country that has only a 10 percent chance of success. The category of first-strike uncertainty is too broad: it equates cases in which an attack would almost certainly fail with those in which it would almost certainly succeed. Whether leaders exhibit equal caution in these two very different situations cannot be deduced; it is an empirical question.

Evidence from the Cold War strongly contradicts the view that the possibility of retaliation is sufficient for robust nuclear deterrence. During the previous period of U.S. nuclear primacy, the cornerstone of American national security strategy was to initiate nuclear war if the Soviets invaded Western Europe. In other words, the U.S. strategy for protecting America's most vital foreign interest hinged on the United States initiating nuclear war—even though there was always the possibility that a small number of Soviet warheads would detonate in the United States. First-strike uncertainty—so-called existential deterrence—was not sufficient to dissuade the United States; as long as U.S. leaders believed they could win a nuclear war, nuclear weapons were the preferred means of defending U.S. vital interests abroad. Revealingly, as the Soviet arsenal grew less vulnerable, the United States abandoned plans to defend Europe by launching an immediate massive nuclear attack.

## *Conclusion*

The debates over nuclear forces during the Cold War suggest that a consensus on the foreign policy implications of U.S. nuclear primacy will remain elusive. "Hawks" will welcome the new era of nuclear primacy, believing that America's dominance in both conventional and nuclear weapons will help de-

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tack would trigger at least a small retaliatory strike. See, for example, Robert Jervis, *The Illogic of American Nuclear Strategy* (Ithaca, N.Y.: Cornell University Press, 1984). In contrast, Goldstein and Hagerty each argue that there is an even lower bar for stable deterrence than the one postulated by advocates of minimal deterrence. Their view (i.e., "existential deterrence") holds that the mere existence of nuclear weapons—and hence the possibility of retaliation—is sufficient for robust nuclear deterrence.

ter potential adversaries from challenging the United States or its allies. For example, China may be deterred from attacking Taiwan if Chinese leaders understand that their small nuclear force is unlikely to prevent the United States from coming to Taiwan's defense—and if they fear that during a crisis or war the United States may be tempted to attack their vulnerable arsenal. Hawks will expect Chinese leaders to reconsider the wisdom of making thinly veiled nuclear threats against the United States.

Arms control analysts—or "owls"—will likely worry that American nuclear primacy may unleash destabilizing forces that undermine U.S. security. The steps that Russia and China take to reduce their vulnerability could create crisis instability and increase the odds of accidental or unauthorized nuclear war. For example, both countries will likely place more of their nuclear forces on higher peacetime alert levels, adopt hair-trigger retaliatory postures, or delegate greater launch authority to lower-level commanders—all of which would raise the risk that nuclear weapons could someday be used against the United States. In short, owls believe that the United States will soon wish it had never pursued nuclear primacy in the first place.

Finally "doves" will not look favorably upon U.S. nuclear primacy, but for different reasons than the owls. They fear the consequences of a newly emboldened, unconstrained, and assertive United States. In an era of U.S. primacy across so many dimensions of power (economic, technological, and military), the greatest fear is overly ambitious foreign policies, fueled by a combination of American hubris and power. According to this view, the pursuit of nuclear primacy is a symptom of the United States' current misguided foreign policy, which may encourage more misguided adventurism in the future.

Our own view is that the wisdom of pursuing nuclear primacy—in fact, the wisdom of developing any set of military capabilities—must be evaluated in the context of a country's foreign policy goals. If the United States continues to pursue global preeminence—defined by the current Bush administration as preventing the emergence of a peer competitor (read: China) and preventing weaker countries from challenging the United States in critical regions such as the Persian Gulf—then the benefits of nuclear primacy may exceed the risks. If, on the other hand, the United States adopts a more restrained foreign policy—for example, one that rejects using force to reverse nuclear proliferation and one that accepts the emergence of China as a great power—then the dangers of increased nuclear arms races and crisis instability would likely trump the benefits.

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Finally, new research on the political utility of nuclear superiority and the strength of the nuclear taboo is needed. Unfortunately, the end of the Cold War

diminished interest in these questions just as high-quality data on decision-making during nuclear crises became available in historical archives.[88] Scholars and policy analysts would be wise to ask whether nuclear primacy will give the United States bargaining leverage in crises with major power adversaries—and, if so, whether the gains outweigh the dangers that nuclear primacy may also bring.

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88. Even countries that provide broad access to their archives typically delay declassification of sensitive strategic documents for at least thirty years. The Cold War ended just as new waves of documents on the crises of the late 1950s and early 1960s were becoming available.

## *Appendix 1*

The following sections explain the targeting strategy and calculations we performed in our model of a U.S. nuclear first strike on Russia.

### ATTACKING ICBM SILOS

Russia's SS-18s are deployed in Type III-F silos; the SS-19s and SS-27s are deployed in the stronger Type III-G Mod silos. Estimates of silo hardness (i.e., resistance to overpressure) for the Type III-F range from 2,000 to 5,000 psi; we use 3,000 psi for the base case and 4,500 psi for the sensitivity analysis. Most estimates for the hardness of Type III-G Mod silos range from 2,000 to 7,000 psi. For the base case, we use 5,000 psi overpressure; in the sensitivity analysis, we use 7,500 psi.[1]

For a warhead that detonates at ground level, its lethal range against a given target can be estimated using:

$$(1)\ LR = 2.62 \times Y^{0.33} / H^{0.33},$$

where $Y$ is the yield in megatons and $H$ is the hardness in psi, and $LR$ is given in nautical miles. The single-shot probability of kill for that warhead is:

$$(2)\ SSPK = 1 - 0.5^{(LR/CEP)\wedge 2}.$$

The *SSPK* must be multiplied by the missile's reliability to estimate the terminal kill probability (*TKP*) per warhead.[2]

Calculations of *TKP* are complicated because the fuse on the W76 warhead cannot be set to detonate at ground level, so for W76 warheads we use graphs that indicate peak overpressure as a function of warhead yield, height of burst, and distance.[3]

### TARGETING RUSSIA'S MOBILE ICBM GARRISONS

Russia's mobile ICBMs spend most of their time in garrison inside concrete shelters.[4] The hardness of these shelters is unknown, so lethal radius calculations were made by assuming that the shelters are similar to "Type 1" structures—the hardest listed by

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1. For estimates of silo hardness, see "Nuclear Weapons Database: Russian Nuclear Delivery Systems" (Washington, D.C.: Center for Defense Information, 2003); and Matthew G. McKinzie, Thomas B. Cochran, and Robert S. Norris, *The U.S. Nuclear War Plan: A Time for Change* (Washington, D.C.: Natural Resources Defense Council, 2001). There is significant uncertainty about the hardness of the newest Russian silos, but our results would not change even if they were substantially more resistant to overpressure. Overpressure is only one of the destructive effects of nuclear detonations. Silos hardened to resist extreme overpressure (e.g., 15,000 psi) would likely be destroyed by a warhead that generated "only" 5,000 psi at the target, because a warhead that detonated close enough to generate 5,000 psi would also create tremendous ground shock and dig a crater that would swallow the silo.

2. Lynn E. Davis and Warner R. Schilling, "All You Ever Wanted to Know about MIRV and ICBM Calculations but Were Not Cleared to Ask," *Journal of Conflict Resolution*, Vol. 17, No. 2 (June 1973), pp. 207-242.

3. Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons* (Washington, D.C.: U.S. Government Printing Office, 1977), fig. 3.73a.

4. For descriptions of their garrisons and shelters, see McKinzie, Cochran, and Norris, *The U.S.*

Samuel Glasstone and Philip Dolan—which are "multistory reinforced concrete building[s] with reinforced concrete walls" and "blast resistant design."[5] We calculate the lethal radius of a given warhead against a Type 1 structure using Figure 5.140 in Glasstone and Dolan.[6]

The only available diagrams of Russian mobile missile garrisons suggest that the shelters are scattered over a relatively small area; the furthest shelters are approximately 400 meters from the garrisons' center.[7] To be conservative, we estimate that each shelter is 500 meters from the center of the garrison. Given the accuracy of the missiles used in the attack (*CEP*) and the distance from the center of the garrison to the shelters (*B*), we can calculate how far a missile fired at the center will detonate, on average, from a given shelter. The median miss distance, *D*, for a warhead aimed at a point a given distance, *B*, from the target is:

$$D = (B^2 + CEP^2)^{1/2}.$$

Using the lethal radius from Figure 5.140 and *D*, we can calculate the *SSPK* using formulas 1 and 2, substituting *D* for *CEP*.

### targeting russian strategic aviation

Russia has 78 strategic bombers stationed at two large bases. Seven other airfields are associated with these aircraft and must be targeted as well.[8] We target each of the nine primary airfields with (1) 2 fast-arriving nuclear airbursts to destroy exposed aircraft and disrupt operations at the base, and (2) follow-on attacks to crater the runways and prevent takeoff by surviving aircraft. Precision is not required for the airbursts over the bases, so 2 fast-arriving warheads should be sufficient to assure at least one detonation near the aimpoint. Cratering the runways, on the other hand, is more demanding.

To determine the probability of a given warhead cratering a runway, we calculate the warhead's lethal radius against runway and the likelihood that the lethal radius covers the entire usable width of the runway. The *LR* of a nuclear attack on a runway is the radius of the crater in the ground; crater size can be calculated if one knows the warhead yield and soil characteristics. We assume that the runways sit on "dry soil or dry soft rock" and calculate crater size (*LR*) by using the standard formulas for this purpose.[9]

We assume that a runway is unusable by large bombers if the crater and thick debris extend out to within 5 meters of the edge of the tarmac. The major runways at Russia's bomber bases are approximately 70 meters wide, so an attack aimed at the center of the runway must ensure that the crater extends out 30 meters from the intended aimpoint. The median distance between the actual point of detonation and the point on the runway that is 5 meters from the edge (*D*) is a function of the 30-meter distance from the

*Nuclear War Plan,* pp. 51–57; and Pavel Podvig, "Current Status of the Strategic Forces," http://russianforces.org/eng/current/.

5. Glasstone and Dolan, *The Effects of Nuclear Weapons*, p. 214.
6. Ibid., p. 219.
7. McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, p. 55.
8. Ibid., pp. 82–84.
9. Glasstone and Dolan, *The Effects of Nuclear Weapons*, pp. 253–256.

aimpoint to the point near the edge (*B*) and the accuracy of the weapon (*CEP*), such that:

$$D = (B^2 + CEP^2)^{1/2}.$$

The probability of a given weapon cutting a given runway can now be calculated with formulas 1 and 2 using crater size as the *LR* and effective accuracy (*D*) in place of *CEP*.

Given that the Russian bomber force is not kept on alert-for example, the nuclear bombs are not stored at the airbase with the bombers-it is unlikely that if any personnel survived the initial two airbursts, they would be able to get the nuclear warheads from storage, and arm and launch their bombers, before the follow-on attack cratered the runways and utterly destroyed the base. In addition to the nine primary bomber bases, there are fifty-four other facilities associated with the Russian bomber force. Each is attacked with two airbursts.

### TARGETING RUSSIAN SUBMARINE BASES

Russia's nine ballistic missile submarines are divided between three primary SSBN bases; together the three bases present thirty aimpoints. Each aimpoint is hit with two fast-arriving SLBM warheads and three warheads from ICBMs and cruise missiles. In addition to the SSBN bases, there are thirty-one other targets (e.g., other major naval bases, shipyards, SLBM loading facilities, and other bases with submarine piers), which present 107 secondary targets, each of which is hit with three warheads, two of which are fast arriving.[10]

Precise numbers are not available for the "hardness" of a surfaced Russian SSBN to the effects of blast overpressure. Previous analyses, however, calculate that a 100-kiloton warhead with a 183-meter *CEP* has a 90 percent chance of doing severe damage to a surfaced Russian SSBN.[11] We can use these numbers (*SSPK* is 0.9 and *CEP* is 183 meters) to solve for *LR* using formula 2, and then solve for submarine hardness using formula 1.[12] According to these calculations, a Russian SSBN can withstand approximately 315 psi. We can now estimate the *SSPK* for any warhead (ground burst) against a submarine located at a pier using formulas 1 and 2. For W76 warheads (which can be used only for air bursts), we use figures that rely on height of burst and warhead yield to calculate peak overpressure at a given distance.[13]

10. For Russian naval targets, see McKinzie, Cochran, and Norris, *The U.S. Nuclear War Plan*, pp. 68–74.
11. Ibid., pp. 70–72.
12. Formula 1 calculates *LR* for targets whose hardness exceeds 1,000 psi. For softer targets (e.g., submarines), a variant is used: $LR = 2.9 \times Y^{0.33}/H^{0.35}$. Michael Salman, Kevin J. Sullivan, and Stephen Van Evera, "Analysis or Propaganda? Measuring American Strategic Nuclear Capability, 1969–88," in Lynn Eden and Steven E. Miller, eds., *Nuclear Arguments: Understanding the Strategic Nuclear Arms and Arms Control Debates* (Ithaca, N.Y.: Cornell University Press, 1989), p. 249.
13. Glasstone and Dolan, *The Effects of Nuclear Weapons*, fig. 3.73a.

## *Appendix 2*

In recent years, several scientists associated with U.S. weapons laboratories have raised concerns about U.S. nuclear warhead reliability. One set of issues relates to the reliability of aging warheads.[1] A second concern is that one U.S. warhead—the W76—may have design flaws that undermine its reliability.[2] Although the details of U.S. nuclear tests are classified, reports suggest that an early test of the W76 in the 1970s "fizzled," meaning that it produced far below the expected yield. Because the W76 is the most common warhead on U.S. SSBNs, reliability problems could reduce U.S. offensive nuclear capabilities.

Despite the publicly voiced concerns, available evidence suggests that the W76 is reliable. First, according to unclassified sources, there was a design flaw in the prototype of the W76; even before the failed test, there were concerns that the warhead might not function properly. The failed test confirmed these fears, and the warhead design was modified before production began. Second, although the number of W76 tests is classified, there have been several tests since the warhead design was fixed, and apparently all were successful. In a recent analysis, Geoff Forden used (1) unclassified information on the production timeline for the W76 and (2) data on the yield of U.S. weapons tests to estimate that there were five to eight tests of the "fixed" W76 between 1973 and 1978. Since then, there were probably three routine "stockpile stewardship" tests before the United States ceased all testing in 1992. There are no reports that any of these eight to eleven tests failed.[3]

Forden uses these numbers to calculate the lowest plausible reliability for the repaired W76. According to his analysis, if the W76 has gone ten for ten since the modifications, there is a 95 percent likelihood that its reliability exceeds 74 percent, and there is a 66 percent likelihood that it exceeds 90 percent. Furthermore, if U.S. officials are concerned about W76 reliability, the warhead probably had a higher-than-normal test rate, meaning that there may have been more than three "stockpile stewardship" tests, and therefore—given the string of successes—an even higher expected warhead reliability rate. Note that the sensitivity analysis in Figures 1–3 suggests that the model results are robust for a broad range of plausible warhead reliability rates.

1 LINE SHORT
REGULAR
1 LINE LONG

1. Jonathan Medalia, *Nuclear Weapons: The Reliable Warhead Replacement Program* (Washington, D.C.: Congressional Research Service, 2005).
2. William J. Broad, "Aging Warheads Ignite a Debate among Scientists," *New York Times*, April 3, 2005; and Fred Kaplan, "Nuclear Options," *Slate.com*, April 15, 2005.
3. Geoff Forden, "U.S. Nuclear Deterrent Is Secure Despite Doubts Cast on Warhead," *Jane's Intelligence Review* (Surry, U.K.: Jane's Information Group, July 2005), pp. 36–37.