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Title: Nuclear Deterrence in the 21st Century: The Role of Science and Engineering

Author(s): Joseph C Martz (PADWP)
Jonathan S. Ventura (PADWP)

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Abstract

Twenty-first century security challenges are multi-polar and asymmetric. A few nations have substantial nuclear arsenals and active nuclear weapons programs that still threaten vital US national security directly or by supporting proliferation. Maintaining a credible US nuclear deterrent and containing further proliferation will continue to be critical to US national security. Overlaid against this security backdrop, the rising worldwide population and its effects on global climate, food, and energy resources are greatly complicating the degree and number of security challenges before policy makers.

This new paradigm requires new ways to assure allies that the United States remains a trusted security partner and to deter potential adversaries from aggressive actions that threaten global stability. Every U.S. President since Truman has affirmed the role of nuclear weapons as a supreme deterrent and protector of last resort of U.S. national security interests. Recently, President Bush called for a nuclear deterrent consistent with the "lowest number of nuclear weapons" that still protects U.S. interests. How can this be achieved? And how can we continue on a path of nuclear reductions while retaining the security benefits of nuclear deterrence? Science and engineering have a key role to play in a potential new paradigm for nuclear deterrence, a concept known as "capability-based deterrence."

Nuclear Deterrence in the 21st Century: The Role of Science and Engineering

Joseph C. Martz & Jonathan S. Ventura
Principal Associate Directorate for Nuclear Weapons
Los Alamos National Laboratory

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For five decades after the Second World War, the role of nuclear weapons in the U.S. defense posture was clear: deter the Soviet Union from attacking the United States and its allies. When the sudden collapse of the Soviet Union ended the Cold War, the role of nuclear deterrence began changing fundamentally. While we retain nuclear weapons as supreme instruments of retaliation, the dynamics of deterrence are evolving to require substantially fewer deployed weapons with a far more diverse set of potential adversaries.

Twenty-first century security challenges are multi-polar and asymmetric. A few nations have substantial nuclear arsenals and active nuclear weapons programs that still threaten vital US national security directly or by supporting proliferation. Maintaining a credible US nuclear deterrent and containing further proliferation will continue to be critical to US national security. Overlaid against this security backdrop, the rising worldwide population and its effects on global climate, food, and energy resources are greatly complicating the degree and number of security challenges before policy makers.

This new paradigm requires new ways to assure allies that the United States remains a trusted security partner and to deter potential adversaries from aggressive actions that threaten global stability. Every U.S. President since Truman has affirmed the role of nuclear weapons as a supreme deterrent and protector of last resort of U.S. national security interests. Recently, President Bush called for a nuclear deterrent consistent with the "lowest number of nuclear weapons" that still protects U.S. interests. How can this be achieved? And how can we continue on a path of nuclear reductions while retaining the security benefits of nuclear deterrence? Science and engineering have a key role to play in a potential new paradigm for nuclear deterrence, a concept known as "capability-based deterrence."

Capability-based deterrence asserts that an agile, assured capability to develop and produce nuclear weapons becomes a deterrent in and of itself. In this view, the country can rely more upon the work of the weapons complex itself and less upon the physical products of that work. This strategy is attractive in that it maintains the benefits of deterrence while enabling the achievement of key goals, such as stockpile reductions. Indeed, the head of the National Nuclear Security Administration (NNSA) stated in December 2007 while introducing the proposed transformation of the nuclear weapons complex, "the United States' future deterrent cannot be based on the old Cold War model of the number of weapons. Rather, it must be based on the capability to respond to any national security situation, and make weapons only if necessary." Capability-based deterrence represents a shift in nuclear policy emphasis, and the role of science and engineering becomes critical to enable the agility and confidence required for this strategy.

The principal elements of capability-based deterrence are the weapons themselves (albeit fewer and potentially designed to the specific requirements of this strategy) along with the design, development, and manufacturing elements of the weapons complex itself. It is not only the capabilities of the forces themselves that assure allies and deter potential adversaries, it is also the capability to sustain and modernize these forces and adapt them to new or emerging threats.

The notion of capability-based deterrence is not new. It appears in the Bush Administration's "new strategic triad" concept and was emphasized in the administration's 2001 Nuclear Posture Review. It was similarly a part of the Clinton Administration's NPR in 1994 and was a principle in the founding of the Stockpile Stewardship Program. This science-based program of experimentation, improved diagnostics, and greatly increased computational capabilities gave us the tools to assess and redress the needs of the stockpile. New experimental facilities for scientific discovery research that strengthens understanding of the physics of weapons performance contributed to the program's remarkable technical success and provides us confidence in the ability to transition to the capability based deterrence.

A most-critical element of this strategy is the timeliness and agility of this capability, because we must detect and respond to a buildup by a potential adversary more quickly than that party can accomplish such a provocative act. An examination of the timing question provides an interesting contrast to the Cold War posture. In decades past, we had to maintain a moments-notice ready response to a provocative act. This led to bombers on constant standby, intercontinental missiles on hair-trigger alert, and submarines on continuous patrol in the world's great oceans. The answer to the timing question was minutes rather than hours or days. Today, the type of threat that might require a large arsenal to counter may not be manifest for many years. Indeed, in an environment of stockpile reductions – both the United States and Russia have reduced their arsenals by more than 90 percent from their Cold War peaks – we no longer require the large counterforce nuclear arsenals that characterized the Cold War.

If changes in the political and international environment allow continued stockpile reductions, the need to resume a Cold War-type posture becomes more remote. Should an adversary decide to restart such an arms race, the investment would be large and the time required sufficiently long that the United States and its allies would have years if not a decades notice. This element is key: several years is sufficient warning that an agile U.S. response could be mounted, and in so doing, potentially deter the initial provocative act. In essence, we move from deterrence through weapons to deterrence through infrastructure and capability. This strategy preserves the benefits of nuclear deterrence while enabling further stockpile reductions. The agility of this strategy – the ability to provide a diverse response to many threats – is also an advantage we don't fully realize while relying solely on a stockpile of Cold War-optimized, high yield-to-weight weapons.

And here the talents of modern science and engineering become most prominent. The agility required to support a capability-based deterrent is grounded in modern science and engineering tools. The challenge is to support a complete cycle of warhead design, certification, development, and production over a three-to-seven-year timeframe. The outdated production complex and '70s-era design practices in our current deterrent do not help achieve this goal. Hence, the NNSA has proposed a transformation of the nuclear weapons complex aimed precisely at enhancing agility and confidence. This is not entirely theoretical. Recent developments within the NNSA complex have demonstrated some key elements of this agility, most notably recent stockpile life-extension program activities as well as the Reliable Replacement Warhead feasibility study.

In the RRW study, design teams provided mature designs in less than 12 months, thanks to modern engineering and design tools. Further, they built demonstration hardware and conducted integrated, non-nuclear proof tests of their designs within 18 months of the feasibility study. These tests exercised much of the production complex in support of RRW and provided a concrete demonstration of agility and timeliness directly relevant to a capability-based deterrent. In the 1980s, this level of maturity required several years of design work. Key tools included modern simulation using supercomputers, use of digital design and engineering tools and databases, digital (paperless) movement of designs to production sites with rapid prototyping and spiral design practices, and rapid proof-level testing with modern experiments provided by the stockpile stewardship program. All of these combined to facilitate agile approaches and designs that promoted confidence.

Equally important in the RRW designs is a relaxation of the central Cold War objective: maximizing yield-to-weight ratios. The RRW designs instead aim for increases in the performance margins, backing away from the highly-tuned "cliffs" characteristic of the legacy stockpile. Wide performance margins in the RRW designs have been coupled with advances in the tools of weapons science to provide very-high-confidence certification of RRW without the need for nuclear testing. Further, advanced safety and security features in the RRW designs allow more efficient safety and security controls within the production complex, greatly improving the efficiency and throughput of manufacturing operations, and substantial protection against unauthorized use of weapons in a wide variety of scenarios. Indeed, the acceptance of the RRW designs as feasible by the Nuclear Weapons Council is important evidence that this goal was achieved and demonstrates an early success of capability-based deterrence.

In sum, a movement toward capability-based deterrence would help the nation meet many important policy objectives, including further reducing the size of the stockpile, continuing to certify the nuclear deterrent without nuclear testing, and fulfilling the country's commitments under the Nuclear Nonproliferation Treaty. Two key enablers of a capability-based deterrent are the transformation of the weapons complex as proposed by NNSA and the adoption of RRW-style designs. The timely and confident demonstration of safe, secure weapon designs recently demonstrated in the RRW feasibility study are an important breakthrough that supports this concept. None of this would have been possible without the application of modern engineering methods and tools as well as the experimental and computational capabilities provided by the Stockpile Stewardship Program.

We should continue to strive for stockpile reductions, but only in an environment in which our security is maintained, allies are assured of our commitments, and adversaries are dissuaded and deterred from potentially aggressive acts. It is our belief that – however near or remote might be a world free of nuclear weapons as envisioned by the NPT – capability-based deterrence working in concert with programs like RRW can facilitate stockpile reductions while maintaining our security and limiting technical risks.

Recommended Reading:

"Toward a Nuclear Free World", George P. Shultz, William J. Perry, Henry A. Kissinger, and Sam Nunn, , Wall Street Journal Editorial, Jan. 15, 2008.

"Minimum Deterrence", Jeffrey Lewis, Bulletin of the Atomic Scientists, Vol. 64 (3) pp.38-41, 2008.

"Can Deterrence be Tailored?" M. Elaine Bunn, Strategic Forum, No. 225, pp. 1-8, 2007.