The Evolving Deterrent

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Nuclear deterrence provided the foundation of our national security strategy for the second half of the 20th century. The end of the Cold War marked the beginning of a period of transition, during which the role of nuclear weapons was uncertain. However, according to national guidance that includes the 2001 Quadrennial Defense Review, the 2002 Nuclear Posture Review, and the 2002 National Security Strategy, as well as the recommendations contained in the 2004 Defense Science Board Task Force report titled "Future Strategic Strike Forces," the direction for nuclear weapons is becoming clearer.

Synthesis of a New Direction

The overall theme of the guidance documents mentioned above is that nuclear weapons have an enduring role for a range of national security objectives, including deterrence. However, the Cold War stockpile needs to be modified to achieve U.S. defense policy goals in the 21st century. The premise of deterrence is that our adversaries believe that, if they attack the United States or our allies with weapons of mass destruction, we have the capability and, if required, the will to destroy what they value most. To deter, we "hold at risk" those assets that are most important to an adversary. Much of the Cold War arsenal was optimized to hold at risk large nuclear forces, leadership facilities, and other important targets in large countries harboring many ready-to-deliver weapons presumably aimed at the United States. As potential adversaries have changed and nonnuclear weapons have improved, the role of nuclear deterrence has evolved toward holding at risk a much smaller number of specific targets that cannot be confidently destroyed by conventional munitions. The perceived requirements of nuclear deterrence and supporting capabilities for an unknown future are the following: Nuclear testing should not be required, collateral damage should be minimized, deterrence plans should be sufficiently flexible to meet emerging or future Department of Defense requirements, the infrastructure should be flexible and responsive if or when needed, environmental problems related to manufacturing must be minimized, cost of manufacturing and operations should be reduced, safety and security in a post 9/11 world need to be improved, and capable and well-trained stewards are necessary to ensure the continued viability of the deterrent. In our judgment, the future deterrent will likely consist of reduced numbers of existing warheads (or functional replacements for them) and the capability to build a modest number of special-capability weapons should that become necessary.

Meeting these kinds of requirements drives the physics package designers from Los Alamos and Lawrence Livermore National Laboratories and the underlying science and technology toward two goals. The first goal is to ensure that the existing systems are sustainable. Achieving this goal is currently based on life extension programs (LEPs) for most of the existing warheads. The planned LEPs are consistent with the Moscow Treaty and the recently revised (June 2004) Nuclear Warhead Stockpile Plan. Another option for achieving this goal is to develop a reliability replacement warhead (RRW)[1] to facilitate replacement of stockpile warheads and warhead components within existing requirements of the current systems. This option is now being examined at Los Alamos. The second goal is to ensure that the NNSA can provide the capabilities that may be needed to hold at risk other potential emerging types of targets, mainly deeply buried command bunkers and biological and chemical weapons, should the need for such weapons be determined by the U.S. government sometime in the future.

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Ensuring the Existing Capability in the 21st Century. Whether to develop additional weapons concepts is a topic of continuing debate, but there is general consensus about the need to ensure that the existing weapon systems are sustainable. To achieve this goal, we need to rely on the underlying science and capability to predict when problems will arise. We then need the capability to replicate the parts, components, and systems in a configuration that is acceptably close to what was tested and certified. Finally, we need capable and trained people to make all this happen.

To date, our Stockpile Stewardship Program (SSP) has been quite successful. We are currently executing LEPs and considering additional LEPs for the remainder of the stockpile, perhaps on a recurring basis. This program, however, is proving to be more time-consuming and expensive than originally envisioned.

Several factors contribute to the expense of the SSP. During the Cold War, U.S. nuclear weapons were designed to meet stringent safety and security requirements while simultaneously meeting very demanding sets of military requirements; these weapons are thus highly optimized. Within a given package, enduring stockpile warheads were designed to have maximum nuclear yield (explosive power) given the highly constrained weight and volume limits of the delivery systems. These optimized, sophisticated designs left little margin for uncertainties of performance. In this context, margin is the generic term that represents the difference between where a variable operates and the upper limit capability of that variable (for example, the difference between the stress in a bridge beam at full load compared with the ultimate stress capability of the beam). Factors providing extra performance margin were secondary. Among them are the weapons' ability to perform "as designed" in a variety of adverse circumstances (for example, extreme heat or cold, radiation environments, and others), to be insensitive to small design flaws or deterioration from aging, and to be straightforward to manufacture and maintain. Considering the factors that provide extra performance margin as secondary in importance was acceptable, in part, because underground nuclear testing could be used to confirm that high-performance designs with moderate design margins would indeed work. Further, because new or replace-

[1] The RRW was recently approved for FY05 funding by the 108th Congress.

ment weapons were constantly being designed, built, and fielded to replace older weapons, age was not a significant consideration. At present, however, new parts and components must be constructed with very tight tolerances on geometry, materials, and manufacturing processes to sustain these highly optimized systems.

Los Alamos is investigating an alternate approach to ensure that the United States can maintain the existing capability through initial examination of the feasibility of an RRW. This feasibility study is concentrating on two major questions: (1) Can we certify a replacement design without nuclear testing? (2) Would such a design provide adequate or more capability with fewer resources?

In answer to the first question, we need to design replacements, bearing in mind that we must certify without nuclear testing. Such designs require development of a different set of requirements. General guidance and constraints must be defined first. A warhead must (1) be certifiable and safe, (2) meet modern surety standards and post 9/11 surety issues, (3) have larger margins with known uncertainties for all physics and engineering design variables (several standard deviations away from known failures using a formal methodology for quantification of margins and uncertainties), (4) be modular and compatible with as many delivery systems as possible, (5) have minimal susceptibility to aging changes, (6) be easier to manufacture than current warheads in the stockpile, (7) be produced for less than typical cost, have fewer parts, and be less complex, (8) whenever possible, contain fewer materials that would pose environmental risk, and (9) be field inspectable and maintainable. An RRW program would also inherently create challenging real-world environments for new stewards.

Los Alamos is building the capability to evaluate the relative costs of different scenarios for stockpile evolution. One can speculate that eight quite highly optimized warhead types (current plan) would cost more than three or four relatively simple long-life systems designed according to the criteria listed above. However, it is important to validate such assumptions before making major investments.

A final issue we will have to address before making a major commitment is the value of stockpile diversity. It has oftentimes been assumed that national security might be better served by a highly diverse stockpile. However, in a fixed-budget, highly constrained environment, the nation must make informed decisions about the value of many warhead types against the advantage of having a better understanding of fewer warhead types. This part of the puzzle is arguably one of the more important issues to be resolved and ultimately may be one of the hardest to address.

Providing Capabilities to Meet Future Threats. The Nuclear Posture Review also calls for the examination of nuclear weapon concepts that would be capable of neutralizing weapons of mass destruction (biological and chemical weapons) and holding at risk hard and deeply buried targets (HDBTs) that could be used to protect an enemy's leaders or key facilities.[2] Because nuclear weapons produce very high temperatures and can produce large amounts of radiation, they are lethal to biological and chemical agents. For example, some preliminary analysis indicates that neutralizing weapons of mass destruction with nuclear weapons would likely cause substantially fewer collateral casualties than might result from dispersal of biological agents under a conventional attack. However, any final assessment of potential collateral damage would require significant research.

HDBTs present a different set of challenges. A significant ground shock is required to destroy many of these types of targets. If a weapon can penetrate the ground, more of the energy is coupled directly into the ground, producing a shockwave. Typically, the effect of an underground burst can be from 20 to 50 times (depending on depth of burial) more effective than an equivalent surface burst. Stated another way, one can lower the required explosive power by the same factor. Current conventional penetrating weapons, holding less than 2000 pounds (or 1 ton) of high explosive, can hold at risk many targets buried at shallow depths. However, numerous critical targets are too deep underground and are too hard to be threatened by these systems. The United States could, in principle, develop a small number of conventional penetrators that are roughly ten times larger than current conventional bombs. These larger systems, although difficult to deliver in any numbers, could be effective at destroying some targets that are not now held at risk by nonnuclear weapons. However, adversaries could easily outdig such a capability. On the other hand, nuclear earth-penetrating weapons could be designed with a range of destructive power. This power could be adjusted to minimize collateral damage while still destroying the target. Collateral damage can be reduced through ground penetration but would produce some air shockwaves (ground shock requirements would be just high enough to destroy the target), thermal radiation, and residual dispersed radiation. However, considerable analysis of weapons' effects is required before a proposal for a warhead can be made. Pursuing these concepts beyond the idea stage is controversial, and recent legislation has removed funding for nuclear earth penetrators or advanced nuclear weapons concepts. ■

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[2] Any decision to actively pursue such weapons must involve the development of Department of Defense requirements and the concurrence of Congress.

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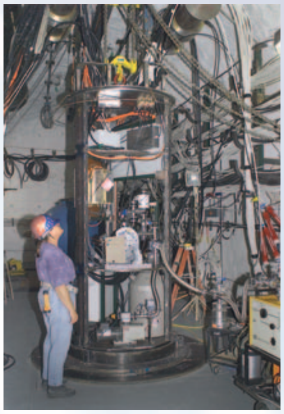

Results from subcritical experiments conducted at the Nevada Test Site are used in building predictive capabilities for stockpile certification.

Warhead disassembly and reassembly are routinely done to ensure that all systems in the stockpile are reliable. The W88 warhead at right has its reentry body wrapped in red protective material for a safer surveillance process. Los Alamos engineers and personnel from the Pantex Plant in Amarillo, Texas, improved the design of the assembly stand to enhance worker safety.

Working with other National Nuclear Security Administration and military organizations, Los Alamos staff help conduct surveillance tests, in which mockups of nuclear weapons are subjected to realistic situations to demonstrate their reliability. In this surveillance test, a B-61 look-alike weapon is dropped from a B-2 bomber (top), recovered (middle), and prepared for post-test data interrogation and radiography (bottom).