For example, destroying a 0.5-kbar target 150 m below the surface requires a 1-kt burst at a buried depth of 10 m. The base surge would be roughly 1.2 km, and an area of 20 km^2 would receive a radiation dose of 50 rem or more from fallout after 48 hours. But what is the alternative? By comparison, without earth penetration, a surface burst of 50 kt would be required to destroy the same target, would produce first-degree burns out to a radius of 5.7 km, and would expose an area of 500 km^2 to a radiation dose of 50 rem or greater from fallout after 48 hours.

Thus, an equivalent surface burst would produce 20 times as much collateral damage as a low-yield earth penetrator. Such comparisons are required if informed choices are to be made about alternate warhead options for the future US nuclear stockpile.

A "sensible strategy" for dealing with chemical or biological munitions in underground storage may be to seal them in place, as Nelson notes. Under some circumstances, this might be accomplished by conventional munitions. For more deeply buried sites, only nuclear warheads likely could produce the shock pressure necessary to collapse an underground storage facility. In addition, the US cannot rule out circumstances that require the prompt, in-place destruction of such munitions. Once again, some of the conventional options that Nelson discusses may accomplish this, although whether such warheads will be sufficiently effective to destroy agents completely and without venting remains to be seen.

Nelson says that conventional weapons currently under development and testing by the US Department of Defense will have the capability for accurate delivery and penetration into the interior of agent storage facilities before detonation. Nuclear options need to be evaluated for difficult or hardened targets, and must be assessed under the same assumptions of accurate delivery and penetrating capability.

Clearly, the detonation of a nuclear explosion in the interior of an agent storage facility would produce a thermal and radiation environment far beyond anything achievable with a conventional warhead. Such interior detonations would not dissipate their energy in heating and dispersing soil and rock, as Nelson suggests, and may be far more effective than conventional ordnance in sanitizing agent stockpiles. Again, only by making fully equivalent comparisons of the effectiveness and relative collateral damage—including nuclear effects—of the full range of conventional and nuclear options can informed choices be made.

We concur with Nelson that many options for lower-yield nuclear weapons with reduced collateral damage could, in principle, be achieved by adaptation of previously tested or existing warheads—depending on the results of thorough scientific and engineering analysis, including detailed computational modeling. The issue of nuclear testing should not be used as a stalking horse to argue against the thoughtful and informed consideration of future options for the US nuclear stockpile.

Sound technical review of all options is vital for defeating current and future threats and for the future US nuclear stockpile. We cannot emphasize that point strongly enough. Congress recently removed its prohibition of R&D on low-yield nuclear weapons, while retaining its long-standing responsibility for any deployment decisions. It is just such R&D that will help enable informed decisions about the future stockpile. And that R&D may help the US decide whether low-yield options with reduced collateral damage would actually help enhance deterrence and dissuasion and, in turn, reduce the risks to US national security as the nation moves toward a much smaller nuclear stockpile envisioned for 2012 and beyond.

This letter expresses the authors' technical views and does not necessarily represent the views of Los Alamos National Laboratory, the University of California, the National Nuclear Security Administration, the US Department of Energy, or the federal government.

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Robert W. Nelson's article is a very timely piece regarding an issue that, because of its grave implications for future arms races and proliferation, is of great importance to international security. Another valuable piece about the relationship of nuclear bunker busters to the greater US nuclear posture is Michael May's article "An Alternative Nuclear Posture" in *Physics & Society*, a newsletter of the American Physical Society's forum on physics and society. The article is available at http://www.aps.org/units/fps/newsletters/2003/october/articles.cfm#2. May argues persuasively that the development of such weapons can be expected to decrease, not increase, the security of the US. Note that May is also a coauthor of one of the articles in reference 3 of Nelson's article.

Jeffrey Marque
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Nelson replies: Jeffrey Marque properly highlights the thoughtful policy and technical analysis by Michael May. A former director of Lawrence Livermore National Laboratory, May concludes, as I do, that "nuclear weapons don't help much with the kinds of missions the US prepares for, including . . . digging

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out deep underground facilities that might contain bio-warfare agents."[1]

I agree with Bryan L. Fearey, Paul C. White, John St. Ledger, and John D. Immele that a nuclear earth-penetrator could collapse a bunker of intermediate depth using a lower-yield warhead than would be required from a surface burst. However, these "reduced collateral damage" nuclear weapons would still result in tens of thousands of casualties if used in an urban environment.[2] And high-yield weapons, with their extreme fallout, would be necessary to destroy bunkers buried deeper than a few hundred meters. The alternative would be to use conventional weapons to collapse the entrances, exits, and ventilation shafts to the underground facility.

A popular scenario in which nuclear use might seem justified is that of a tyrant threatening to use chemical and biological weapons stored in an underground bunker. However, Fearey and coauthors mischaracterize my article as implying that a nuclear earth-penetrator would be an effective weapon to sterilize these buried agents. For that to be the case, the geometry of the shallow bunker must be known precisely, and the weapon must be guided to penetrate the very underground room where the enemy has conveniently placed all chem–bio stocks. A near miss would more likely spread active chemical or biological agents into the environment rather than destroy them.[3] The intelligence community's identification of "590 suspect chemical and biological weapon sites"[4] just before the recent war in Iraq might give one pause.

At best, proposed bunker-busting weapons would add only marginal improvements to current US nuclear capabilities. Yet building such weapons would reverse the decade-long US commitment—initiated in 1992 by President George H. W. Bush and extended by President Bill Clinton—to halting further development of new nuclear weapons and to a moratorium on nuclear testing. Similar commitments by all five of the nuclear powers were essential to gain support for the 1995 extension of the Nuclear Nonproliferation Treaty. Breaking those commitments could threaten the nuclear nonproliferation regime.

But even if the US ignores its international commitments, it is in our security interest to continue to deemphasize the utility of nuclear weapons. Again, quoting May:

> Given the overwhelming US conventional advantage and the relative invulnerability of the US to all but nuclear weapons, the US nuclear posture should aim at minimizing the chances of nuclear weapons spread rather than seeking marginal gains with tactical nuclear weapons. Nuclear weapons are equalizers. Why bring them back into the forefront of regional problems, whether in the Middle East or anywhere else?

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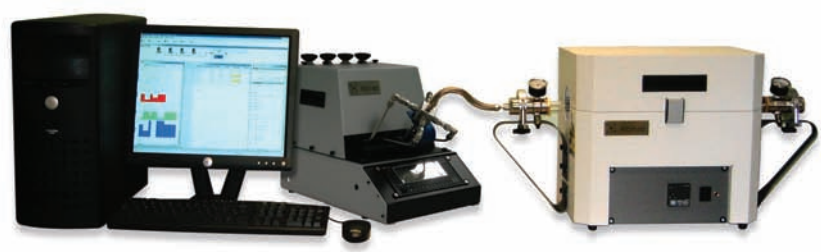

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