GlobalResearch
Center for Research on Globalization

Low-Yield Earth-Penetrating Nuclear Weapons

Review Article

By Robert W. Nelson
Global Research, February 12, 2006
Federation of American Scientists Publicv Interest Report, January/February 2001 1 January 2001

Theme: Militarization and WMD
In-depth Report: Nuclear War

FEDERATION OF AMERICAN SCIENTISTS

Fig. 1 *Diagrams like this one give the false impression that a low-yield earth penetrating nuclear weapon would "limit collateral damage" and therefore be relatively safe to use. In fact, because of the large amount of radioactive dirt thrown out in the explosion, the hypothetical 5-kiloton weapon discussed in the accompanying article would produce a large area of lethal fallout. (Philadelphia Inquirer/ Cynthia Greer, 16 October 2000.)*

Despite the global sense of relief and hope that the nuclear arms race ended with the Cold War, an increasingly vocal group of politicians, military officials and leaders of America's nuclear weapon laboratories are urging the US to develop a new generation of precision low-yield nuclear weapons. Rather than deterring warfare with another nuclear power, however, they suggest these weapons could be used in conventional conflicts with third-world nations.

Critics argue that adding low-yield warheads to the world's nuclear inventory simply makes their eventual use more likely. In fact, a 1994 law currently prohibits the nuclear laboratories from undertaking research and development that could lead to a precision nuclear weapon of less than 5 kilotons (KT), because "low-yield nuclear weapons blur the distinction between nuclear and conventional war."

Last year, Senate Republicans John Warner (R-VA) and Wayne Allard (R-CO) buried a small provision in the 2001 Defense Authorization Bill that would have overturned these earlier restrictions. Although the language in the final Act was watered down, the Energy and Defense Departments are still required to undertake a study of low-yield nuclear weapons that could penetrate deep into the earth before detonating so as to "threaten hard and deeply buried targets." Legislation for long-term research and actual development of low-yield nuclear weapons will almost certainly be proposed again in the current session of Congress.

Senators Warner and Allard imagine these nuclear weapons could be used in small-scale conventional conflicts against rogue dictators, while leaving most of the civilian population untouched. As one anonymous former Pentagon official put it to the *Washington Post* last spring,

"What's needed now is something that can threaten a bunker tunneled under 300 meters of granite without killing the surrounding civilian population."

Statements like these promote the illusion that nuclear weapons could be used in ways which minimize their "collateral damage," making them acceptable tools to be used like conventional weapons.

As described in detail below, however, the use of any nuclear weapon capable of destroying a buried target that is otherwise immune to conventional attack will necessarily produce enormous numbers of civilian casualties. No earth-burrowing missile can penetrate deep enough into the earth to contain an explosion with a nuclear yield even as small as 1 percent of the 15 kiloton Hiroshima weapon. The explosion simply blows out a massive crater of radioactive dirt, which rains down on the local region with an especially intense and deadly fallout.

Moreover, as Congress understood in 1994, by seeking to produce usable low-yield nuclear weapons, we risk blurring the now sharp line separating nuclear and conventional warfare, and provide legitimacy for other nations to similarly consider using nuclear weapons in regional wars.

Conventional Earth-Penetrating Weapons

FAS FEDERATION OF AMERICAN SCIENTISTS

Fig. 2 *The Pentagon has a growing collection of high precision conventional weapons capable of defeating hardened targets. In this sled-driven test, the GBU-28 laser guided bomb with its improved BLU-113 warhead penetrates several meters of reinforced concrete.*
Fig. 3 *A B2 bomber releases an unarmed B61-11 earth-penetrating bomb during tests in Alaska. Despite falling from an altitude of 40,000 feet, this bomb burrowed only approximately 20 feet into the soil. Any nuclear blast at this shallow depth would not be contained, and would produce intense local fallout.*

Video clips from CNN (2.2MB) and Lockheed Martin (2.8MB)

The Pentagon already has a number of conventional weapons capable of destroying hardened targets buried within approximately 50 feet of the surface. The most well-known of these is the GBU-28 developed and deployed in the final weeks of the air campaign in the Gulf War. The Air Force was initially unable to destroy a well-protected bunker north of Baghdad after repeated direct hits. The 4000 lb GBU-28 was created from a very heavy surplus Army eight-inch gun tube filled with conventional explosive and a modified laser guidance kit. It destroyed the bunker, which was protected by more than 30 feet of earth, concrete and hardened steel.

The precision, penetrating capability, and explosive power of these conventional weapons has improved dramatically over the last decade, and these trends will certainly continue. Indeed, the GBU-37 guided bomb, a successor to the GBU-28, is already thought to be capable of disabling a silo based ICBM — a target formerly thought vulnerable only to nuclear attack. In the near future, the United States will deploy new classes of hard target penetrators which can land within one to two meters of their targets.

The B61-11 Nuclear Bomb

However, mini-nuke advocates — mostly coming from the nuclear weapons labs — argue that low-yield nuclear weapons should be designed to destroy even deeper targets.

The US introduced an earth-penetrating nuclear weapon in 1997, the B61-11, by putting the nuclear explosive from an earlier bomb design into a hardened steel casing with a new nose cone to provide ground penetration capability. The deployment was controversial because of official US policy not to develop new nuclear weapons. The DOE and the weapons labs have consistently argued, however, that the B61-11 is merely a “modification” of an older delivery system, because it used an existing “physics package.”

The earth-penetrating capability of the B61-11 is fairly limited, however. Tests show it penetrates only 20 feet or so into dry earth when dropped from an altitude of 40,000 feet. Even so, by burying itself into the ground before detonation, a much higher proportion of the explosion energy is transferred to ground shock compared to a surface bursts. Any attempt to use it in an urban environment, however, would result in massive civilian casualties. Even at the low end of its 0.3-300 kiloton yield range, the nuclear blast will simply blow out a huge crater of radioactive material, creating a lethal gamma-radiation field over a large area.

Containment

Just how deep must an underground nuclear explosion be buried in order for the blast and fallout to be contained?

The US conducted a series of underground nuclear explosions in the 1960s — the Plowshare tests — to investigate the possible use of nuclear explosives for excavation purposes. Those performed prior to the 1963 Atmospheric Test Ban Treaty, such as the Sedan test shown in Figure 4, were buried at relatively shallow depths to maximize the size of the crater produced.

Fig. 4 *The 100 KT Sedan nuclear explosion, one of the Plowshares excavation tests, was buried at a depth of 635 feet. The main cloud and base surge are typical of shallow-buried nuclear explosions. The cloud is highly contaminated with radioactive dust particles and produces an intense local fallout.*

In addition to the immediate effects of blast, air shock, and thermal radiation, shallow nuclear explosions produce especially intense local radioactive fallout. The fireball breaks through the surface of the earth, carrying into the air large amounts of dirt and debris. This material has been exposed to the intense neutron flux from the nuclear detonation, which adds to the radioactivity from the fission products. The cloud typically consists of a narrow column and a broad base surge of air filled with radioactive dust which expands to a radius of over a mile for a 5 kiloton explosion.1 In the Plowshare tests, roughly 50 percent of the total radioactivity produced in the explosion was distributed as local fallout — the other half being confined to the highly-radioactive crater.

In order to be fully contained, nuclear explosions at the Nevada Test Site must be buried at a depth of 650 feet for a 5 kiloton explosive — 1300 feet for a 100-kiloton explosive.2 Even then, there are many documented cases where carefully sealed shafts ruptured and released radioactivity to the local environment.

Therefore, even if an earth penetrating missile were somehow able to drill hundreds of feet into the ground and then detonate, the explosion would likely shower the surrounding region with highly radioactive dust and gas.

Long-Rod Penetration

Fig. 5 *Underground nuclear tests must be buried at large depths and carefully sealed in order to fully contain the explosion. Shallower bursts produce large craters and intense local fallout. The situation shown here is for an explosion with a 1 KT yield and the depths shown are in feet. Even a 0.1 KT burst must be buried at a depth of approximately 230 feet to be fully contained. (Adapted from Terry Wallace, with permission.)*

It is straightforward to show, however, that the maximum penetration depth is severely limited if the missile casing is to remain intact. One can make reasonably accurate estimates of the penetration depth based on the well-developed theory of "long-rod penetration." The fundamental parameter *R* is the ratio of the projectile ram pressure to the yield strength of the material.3 The target material yields, and penetration occurs, when *R* is greater than one. For a steel rod to penetrate concrete, the minimum velocities for penetration is about one half a kilometer per second (1100 miles per hour). For ductile materials, the kinetic energy lost from the penetrator can deform the target and dig out a penetration crater.

Fundamentally, however, the depth of penetration is limited by the yield strength of the penetrator — in this case, the missile casing. Even for the strongest materials, impact velocities greater than a few kilometers per second will substantially deform and even melt the impactor.

An earth-penetrating nuclear weapon must protect the warhead and its associated electronics while it burrows into the ground. This severely limits the missile to impact velocities of less than about three kilometers per second for missile cases made from the very hardest steels. From the theory of "long-rod penetration," in this limit the maximum possible depth *D* of penetration is proportional to the length and density of the penetrator and inversely proportional to the density of the target. The maximum depth of penetration depends only weakly on the yield strength of the penetrator.[4] For typical values for steel and concrete, we expect an upper bound to the penetration depth to be roughly 10 times the missile length, or about 100 feet for a 10 foot missile. In actual practice the impact velocity and penetration depth must be well below this to ensure the missile and its contents are not severely damaged.

Given these constraints, it is simply not possible for a kinetic energy weapon to penetrate deeply enough into the earth to contain a nuclear explosion.

The Weapons Labs and the CTBT

The most vocal proponents of new small-yield weapons come from the nation's nuclear weapons laboratories, at Los Alamos and Livermore.

In a 1991 *Strategic Affairs* article entitled "Countering the Threat of the Well-armed Tyrant," Los Alamos weapons analysts Thomas Dowler and Joseph Howard II, argued that the US has no proportionate response to a rogue dictator who uses chemical or biological weapons against US troops. Our smallest nuclear weapons — those with Hiroshima-size yields—would be so devastating that no US president could use them. We would be "self-deterred." To counter this dilemma, they argued the US should develop "mininukes," with yields equivalent to 0.01-1 KT: "… nuclear weapons with very low yields could provide an effective response for countering the enemy in such a crisis, while not violating the principle of proportionality."

More recently, in a speech to the Nuclear Security Decisionmakers Forum, Sandia Laboratory Director Paul Robinson stated

"The US will undoubtedly require a new nuclear weapon … because it is realized that the yields of the weapons left over from the Cold War are too high for addressing the deterrence requirements of a multi polar, widely proliferated world. Without rectifying that situation, we would end up being self-deterred."

A more cynical interpretation of these statements is that the laboratory staff and leadership simply feel threatened by the current restrictions on their activities, and want to generate a new mission (and the associated funding) to keep them in operation indefinitely. Indeed, beginning in 1990 with the collapse of the Soviet Union and the end of the Cold War, there was serious discussion of closing one of the bomb labs.

Moreover, President Clinton ended US nuclear testing in 1993, and signed the Comprehensive Test Ban Treaty (CTBT) — a permanent worldwide ban on nuclear testing — in 1996. Despite the Senate's failure to ratify the CTBT in 1999, its proponents believe the treaty will eventually come into force. The major nuclear powers continue to abide by the world moratorium on nuclear testing, and even India and Pakistan appear to have joined the moratorium after their May 1998 nuclear tests.

The nuclear weapons labs are particularly threatened by the CTBT, since it will probably limit them to maintaining the stockpile of weapons already in our arsenal. Keeping young scientists interested in the weapons program is especially difficult when their main job is the relatively mundane task of assuring reliability. The labs desire the challenge of designing new nuclear weapons, simply for the scientific and technical training experience the effort would bring. Hence, there is tremendous pressure to create a new mission that justifies a new development program.

But could the US deploy a new low-yield nuclear earth-penetrating weapon without testing it? Under continued political pressure to support the Test Ban and its related Stockpile Stewardship Program, Los Alamos Associate Director Steve Younger has stated, "one could design and deploy a new set of nuclear weapons that do not require nuclear testing to be certified. However, … such simple devices would be based on a very limited nuclear test database."

On the other hand, it seems unlikely that a warhead capable of performing such an extraordinary mission as destroying a deeply buried and hardened bunker could be deployed without full-scale testing. First, even if the missile casing were able to withstand the high-velocity ground impact, the warhead "physics package" and accompanying electronics must function under extreme conditions. The primary device must detonate and produce a reliable yield shortly after suffering an intense shock deceleration. Second, there must be great confidence that the actual nuclear yield is not greater than expected. Since the natural energy scale for a fission nuclear weapon is of order 10 KT, much lower yield weapons must be sensitive to exacting design tolerances; the final yield is determined by an exponentially growing number of fission-produced neutrons, so the total number of neutron generations must be finely-tuned. Given that these weapons may be used near population centers, it thus seems highly unlikely that designers could certify a low-yield warhead without actually testing it.

What would be the consequence if the US decides to go ahead and test a new generation of nuclear weapons? As House Democrats expressed in a letter to Rep. Ike Skelton of Missouri, the ranking Democrat on the House Armed Services Committee,

"The resumption of nuclear test explosions that will result from such a program involving nuclear weapons would decrease rather than increase our national security and undermine US and international non-proliferation efforts."

If the US abandons the moratorium, Russia and China will almost certainly respond in kind — destroying prospects for eventual passage of the CTBT.

Conclusion

Proponents of building a new generation of small nuclear weapons have seldom been specific about situations where nuclear devices would be able to perform a unique mission. The one clear scenario is using these warheads as a substitute for conventional weapons to attack deeply buried facilities. Based on the analysis here, however, this mission does not appear possible without causing massive radioactive contamination. No American president would elect to use nuclear weapons in this situation — unless another country had already used nuclear weapons against us.

The end of the Cold War should allow us to place further limits on the development and use of nuclear weapons. The danger of moving from a conventional to a nuclear war is so enormous, that the US refrained from using nuclear weapons in Korea even when US troops were in danger of being overwhelmed. Attempts to develop a new generation of low-yield nuclear weapons would only make nuclear war more likely, and they seem cynically designed to provide legitimacy to nuclear testing – steps that would return us to the dangers of Cold War nuclear competition, but with a larger number of nations participating.

Robert W. Nelson, a theoretical physicist who works on technical arms control issues, is on the research staff of Princeton University and a consultant to FAS.

Notes:

1The base surge radius scales roughly as 4000 *W*1/3*kt* feet, where *Wkt* is the yield in kilotons.

2In general, NTS tests are buried at depths of *D* 450 *Wkt*1/3.4 feet to be fully contained.

3*R* = v2 / 2*Y* = (v/v*c*) 2 where is the projectile density, v is its velocity, *Y* is the yield strength of the material, and the critical velocity v*c* = (2*Y* /)1/2

4For a penetrator which is much stronger than the target, *D/L* (*p* / *t*) ln(*Yp* / *Yt*), where *L* is the length of the penetrator, is the material density, and *Y* is the material strength to plastic yielding; the subscripts *p* and *t* stand for the penetrator and target.

January/February 2001, 2006

Comment on Global Research Articles on our Facebook page

Become a Member of Global Research

Articles by: **Robert W. Nelson**