Earth-Penetrating Weapons
Union of Concerned Scientists Backgrounder

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The administration’s defense budget contains $15.5 million to study a new nuclear earth-penetrating weapon—the Robust Nuclear Earth Penetrator (RNEP), and Congress is currently debating whether to fund this study. This backgrounder provides information on the technical aspects of earth penetrators, current US capabilities, and the plans for and implications of developing new nuclear weapons for this role.

Earth-Penetrating Weapons: Underlying Principles and other Technical Aspects

An earth-penetrating warhead (EPW) is designed to hit the earth at high speed and penetrate into the ground before exploding. Such weapons can be delivered by missiles or aircraft, and are intended primarily to attack underground targets.

However, an earth-penetrating warhead is not designed to reach targets buried deep underground and then explode. Indeed, the earth slows the warhead so quickly that it cannot penetrate very deeply. Rather, by exploding underground instead of at or above the surface, a much larger fraction of the energy of the explosion is transmitted to the ground, where it creates a strong seismic shock wave that can then propagate to and destroy or damage an underground target. Even a short penetration distance accomplishes this goal of “coupling” the energy of the explosion to the ground: penetration of a few meters increases the underground destructive effects by more than a factor of ten for a wide range of warhead yields.

For example, exploding a 10-kiloton nuclear weapon at a depth of one meter would increase the effective yield by a factor of 20, resulting in underground damage equivalent to that of a 200-kiloton weapon exploded at the surface of the ground. But increasing the penetration depth to five meters would only increase the effective yield by an additional 60%, to 320 kilotons.

Radioactive Fallout from a Nuclear EPW

A commonly held fallacy is that an earth-penetrating nuclear weapon can penetrate deeply enough to contain all the radioactive fallout. This is not the case.

Penetration Depth

While the penetration depth increases as the impact velocity is increased, the penetrator will destroy itself if it strikes the ground at too high a speed. Empirical data obtained by firing solid steel projectiles into concrete shows that the maximum impact velocity in this case is roughly one kilometer per second and the maximum achievable penetration depth of such a projectile in concrete is roughly four times its length. However, in practice, lower impact velocities may be chosen to...

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reduce the deceleration experienced by the warhead, which would then result in still less penetration. Thus, the maximum penetration depth in concrete of a three-meter long EPW would be less than 12 meters, and may be substantially less. Penetration depths will be larger in dry soil than concrete or rock, but one would have to expect that a hardened target would be placed below hard rock or concrete.

**Containment Depth**

The depth at which even a small nuclear weapon must be buried to ensure that it is “contained” — that is, that no radiation is released when it explodes—is much greater than the achievable penetration depth, so that it is impossible to prevent radioactive fallout from a nuclear EPW.

For example, the minimum burial depth to ensure containment at the US Nevada Test Site was empirically determined, and is roughly 100 meters for a one kiloton explosion and 500 meters for a 100 kiloton explosion. In dry hard rock, the required depths would be roughly 60 meters for a one-kiloton explosion and 300 meters for a 100-kiloton explosion. These depths are far greater than what can be achieved by a penetrator.

Moreover, even if sufficient penetration depths could be achieved, the explosion would still not be contained since penetrating the earth (rather than burying an explosive) creates an open shaft through which radiation would leak to the surface.

Since an EPW will not penetrate enough to be fully contained, it will produce a surface crater when it explodes, and large amounts of radioactive dust and debris from the crater will be ejected into the air and surrounding region. The size of the crater—and the amount of material ejected—will depend on the local ground properties, the depth of the explosion, and the yield of the weapon. The level of fallout will also depend on the local weather conditions, such as wind and rain.

**Current US EPW Capabilities**

The United States currently deploys both conventional and nuclear earth-penetrating weapons. The two largest conventional EPWs (called GBU-28 and GBU-37) use the same body but different guidance systems. The bodies are long tubes, a third of a meter (14.5 inches) in diameter and four meters (12.8 feet) long, that weigh over two tons and contain nearly 300 kilograms (630 pounds) of high explosive. Both are dropped from aircraft, and tests have shown they can penetrate six meters of concrete or 30 meters of earth. The GBU-28 is laser guided and the GBU-37 is guided by the Global Positioning System, which reportedly makes it more accurate than the GBU-28 and allows it to operate under all weather conditions. Very high accuracy increases the ability of these weapons to destroy shallow hardened targets with known locations (such as missile silos) but not deeply buried targets.

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3 Nelson, “Low Yield.”
6 The United States has or is developing a number of other conventional penetrators for delivery by aircraft and cruise missiles. See, for example, “Report to Congress on the Defeat of Hard and Deeply Buried Targets,” July 2001, pp. 16-18, available at www.nukewatch.org/important_documents.html#HDBT
The United States reportedly stockpiles about fifty B61-11 nuclear EPWs, which—like the conventional alternatives—are dropped from aircraft. This bomb was designed during the 1991 Gulf War and entered the stockpile in the late 1990s. It is a modification of the B61-7 bomb with a new casing, and reportedly has a variable yield, from 0.3 to 340 kilotons. It is shorter than the GBU-28, with a length of 3.6 meters, and has only a quarter of the mass. It reportedly can penetrate two to three meters in frozen soil.

For a penetration depth of three meters and a yield of 0.3 kilotons, the B61-11 could destroy a target buried under roughly 15 meters of hard rock or concrete. For the same penetration depth and the maximum yield of 340 kilotons, the destruction depth would be roughly 70 meters for a hardened target.

In the 1980s the United States developed and tested but did not deploy a nuclear EPW intended for the intermediate-range Pershing II missile. This warhead, called the W86, was also a modification of the B61. It was about two meters long and 0.2 meters in diameter, and could penetrate less than 10 meters of granite or hardened concrete. The main mission of this weapon was to crater runways rather than attack buried targets.

Plans for New Nuclear Earth-Penetrating Weapons

In principle, a new nuclear EPW that has a greater capability to destroy deep, hardened targets than does the B61-11 could be achieved by increasing the penetration depth and/or the explosive yield. However, while a new penetrator design could increase the penetration depth somewhat, the above discussion shows that it is very unlikely that the penetration depth could be increased enough to result in a significant increase in the destructive capability of the weapon. Instead, increasing destructive capability significantly would require increasing the yield of the nuclear warhead. This appears to be what the Bush administration has in mind.

According to Senate testimony by Everett Beckner, the Deputy Administrator for Defense Programs of the National Nuclear Security Administration, the proposed study of the new Robust Nuclear Earth Penetrator (RNEP) would include modifying two existing nuclear weapons to allow them to attack buried targets—the B61 (which is already the basis for the B61-11 earth penetrator), but also the B83 air-dropped bomb. The B83 warhead is currently the largest warhead the United States deploys, reportedly having a yield of one to two megatons—much larger than the maximum yield of the current B61-11 EPW.

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7 For information on the modifications made to the B61, see the statements by then Sandia Laboratory Vice President for National Security Programs Roger Hagengruber in “B61-11 a Modification, Not a New Weapon,” Sandia Lab News, 1 August 1997, available at www.sandia.gov/LabNews/LN08-01-97/b61_story.html.
10 Nelson, “Low Yield.”
11 Glasstone and Dolan, Effects, p. 256, Figure 6.72b. This table gives values for the apparent crater depth of a nuclear explosion. We assume a target could be destroyed to a depth 50% greater than this.
12 Mello, “New Bomb.”
Besides developing new cases for these warheads, other possible modifications include improved guidance systems for higher accuracy (which would increase the destructive capability against shallow, but not deep, hardened targets), better attitude control at impact (which would help ensure that the penetrator hits the ground at the right angle so it is not simply deflected from the earth’s surface), and smarter fuzes (which would increase control over where the weapon explodes and make sure that it is not detonated by hitting structures above ground).

The B61-11 EPW was produced without nuclear testing, since it was essentially a repackaging of an existing warhead. Similarly, it appears that other options currently being considered would use existing warheads and would therefore not require nuclear testing.

**Political Implications of a New Nuclear EPW**

A US decision to develop new nuclear earth-penetrating weapons would have several negative political implications internationally. First, such weapons are explicitly designed to be more “usable” and to be used in what would otherwise be a non-nuclear conflict. As a result, they blur the line between conventional and nuclear weapons and lower the threshold for nuclear use. Second, by contravening US pledges under the Nuclear Non-Proliferation Treaty (NPT) not to target non-nuclear weapon states with nuclear weapons, such weapons undermine the non-proliferation regime.

**Lowering the Threshold for Nuclear Use**

The Bush administration’s Nuclear Posture Review (NPR), which was completed earlier this year, explicitly calls for US nuclear weapons to deter and respond to a “wide range of threats,” including attacks by conventional, chemical, or biological weapons as well as “surprising military developments.” In keeping with its stated interest in increasing the roles for US nuclear weapons, the NPR also calls for “improved earth penetrating weapons (EPWs) to counter the increased use by potential adversaries of hardened and deeply buried facilities.” While the United States has never forsworn the first use of nuclear weapons, the Bush NPR carries this policy further and makes it more explicit. The proposed study of the new Robust Nuclear Earth Penetrator would be part of this effort to increase US nuclear attack options and capabilities.

However, this policy is counter to US and international security interests. Maintaining and strengthening the firebreak against the use of nuclear weapons by all countries should be a paramount concern for US national security. Thus, the sole purpose for US nuclear weapons should be to deter the use of nuclear weapons and, if necessary, to respond to nuclear attacks. The additional roles for nuclear weapons called for by the Bush posture review would undermine the overriding goal of preventing the proliferation and use of nuclear weapons. If the United States, with unquestioned conventional superiority, chooses to rely on nuclear weapons, then weaker states—particularly those not covered by US security guarantees—would apparently have a far greater need for nuclear weapons. Ultimately, this policy of first use will encourage the proliferation of nuclear weapons.

**Breaking US Pledges under the NPT**

The Bush NPR explicitly calls for targeting nuclear weapons against several non-nuclear weapon state signatories to the NPT, which is contrary to previous US pledges to not do so. Such pledges were made by all the nuclear weapon state signatories to the NPT as an incentive for other countries to renounce nuclear weapons. By developing new nuclear weapons expressly to target non-nuclear weapon states, the United States would undermine the continued viability of the NPT. In short, the security costs of developing such weapons outweigh any conceivable security benefits.