US nuclear deterrent is secure despite doubts cast on warhead

A debate within US weapons laboratories over the reliability of the W-76 Trident warhead became public in April after a New York Times article reported that several nuclear weapons experts believed up to three-quarters of the US nuclear force could be defective. Geoff Forden examines the test statistics and the implications of possible defects.

janes.com

This article was first available online on 13 June 2005.

Related Articles

1 North Korean declaration puts ball in Washington's court
2 US nuclear arsenal: less is more
3 Arms control treaties/Treaty on the Non-proliferation of Nuclear Weapons (NPT) 1 July 1970

Search for these articles at www.janes.com

A problem with the W-76 Trident warhead could render the US unable to retaliate in the event of a daring first strike against the two land-based components of its triad of strategic forces. With the silo-based inter-continental ballistic missiles (ICBMs) and nuclear-capable bomber force destroyed, the US would be forced to rely on a submarine-based force that some scientists say has questionable reliability.

Although such a sneak attack is highly unlikely, it may not always be the case. This fear, combined with the publicity generated by a *New York Times* article on 3 April, has fed a debate on whether the US should break with its obligations under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in order to design and test new nuclear weapons. Such a move could, however, damage US credibility and make it harder to persuade Iran or North Korea to forego any nuclear aspirations they might have.

While even historical costs of warhead production remain top secret, scholars from the Brookings Institution, a Washington-based think-tank, estimated that each new warhead would cost US$6 million to manufacture. If the US were to replace all 1,280 of its W-76 warheads with new units, it would cost around $7.5 billion, considerably more than the current $2 billion plus life extension programme. Such an expensive programme, especially when more pressing needs are competing for each defence dollar, could not be undertaken without sufficient cause.

Empics/1119752

• The US nuclear submarine, the USS *Alaska*. Some nuclear weapons experts say submarine-based warheads have questionable reliability.

The criticism of the W-76

A modern strategic nuclear warhead, such as the W-76, consists of two stages with most of its explosive power coming from the second, or thermonuclear, stage. These parts of the warhead are called stages because the nuclear detonation of the first stage causes the second stage to explode.

The initial or primary stage is built around a core containing a thin shell, or pit, of fissionable material. Inside the hollow pit, a mixture of tritium and deuterium gas is used to boost its explosive yield. This arrangement, when compressed by conventional explosives, detonates with roughly the power of the bombs dropped on Hiroshima or Nagasaki during the Second World War. The mainly soft x-ray radiation emitted by this initial nuclear bomb is focused onto the secondary by the radiation case, which surrounds both the primary and secondary.

The case is made from a dense, so-called 'high-Z', material such as Uranium or Tungsten so it can efficiently focus this radiation. Inside the radiation case, the secondary stage comprises of axially symmetric layers of depleted uranium (called the 'pusher'), a layer of lithium-6 deuteride to furnish the main source of fusion energy, and a layer of fissile material known as the 'sparkplug'. At the centre of the sparkplug is a gas comprised of tritium and deuterium.

If all works as designed, the focused radiation ablates the outer surface of the pusher plate, causing a large reactive force that rapidly and evenly compresses the secondary. This squeezes the fissile material core to super criticality, causing it to fission. The tritium and deuterium gas serves to boost the yield. Neutrons from the fissioning sparkplug convert the surrounding layer's lithium-6 to tritium, forming the necessary fuel for fusion. The newly made fusion fuel, caught between internal fissioning core and the imploding pusher plate, is then compressed to approximately 1,000 times its original density and heated until the material undergoes a fusion reaction. If the compression is not evenly distributed, the contents of the secondary could squirt out the side before fusion can be achieved.

Dr Richard L Morse, who directed advanced bomb design concepts at Los Alamos National Laboratory, contends that this is exactly what could happen to a large portion of the operational W-76s. Critics point to the fact that the radiation shell surrounding the W-76 is as 'thin as a beer can' in places as a design flaw and could cause warhead failures not related to ageing. This, they claim, could cause what is known as Rayleigh-Taylor instability, meaning that the expanding material and energy within the radiation shell causes the surrounding metal to break up into irregular strands rather than a symmetrical surface. In turn, these irregularities would not focus the radiation to uniformly compress the inner fusion device, causing it to fail to react or react with a substantially lower yield.

Such worries gain some credibility since a prototype W-76 is said to have produced a substantially lower yield than expected during a test in the early 1970s. This was associated with a minor design change that was, presumably, reversed. It was not, however, the only thermonuclear weapon to produce a significantly lower than expected yield during a test. For instance, the W-78, developed a few years later by Los Alamos for the Minuteman III ICBM, fizzled - a result that was predicted by computer simulations performed at Lawrence Livermore.

Limits on reliability

Almost everything about testing nuclear weapons is secret. However, the underground nuclear tests at the Nevada test site have been listed together with a rough indication of the experimental yield, such as it being 'less than 20 kiloton (kT)' or 'between 20 kT and 150 kT'. This information, together with the developmental histories of nuclear weapons publicly available, can be used to find the correlation between warhead development and underground testing.

Nuclear explosions were performed for a number of reasons. These included development of new weapons, testing new weapons concepts before a formal weapon design was proposed, and ensuring that the nuclear stockpile was reliable. This analysis is solely concerned with tests of complete thermonuclear weapons since the problems critics claim are associated with the W-76 are hypothesised to involve compressing the secondary enough to cause fusion. Therefore, tests listed as less than 20 kT were ignored as either tests of tactical weapons (such as atomic artillery shells such as the W-79) or tests of primaries only.

Test dates associated with thermonuclear explosions were then correlated with known periods of warhead development: the development engineering, production engineering and pilot production phases. Rates of stockpile surveillance tests were estimated by using the three thermonuclear tests performed in the 16 months after the last warhead development project was cancelled in August 1991 and when the US voluntarily entered the current testing moratorium.

The results of this analysis indicate that there were one or two thermonuclear tests of the W-76 during the 31 month-long, first development engineering phase, assuming that there was the same rate of stockpile surveillance testing then as just before the current moratorium. Typically, a weapon design is not completely finalised during the first or developmental engineering phase of development. The second, or production-engineering phase, concentrates on developing the equipment needed to fabricate the warhead during quantity production. During this phase, the design is fixed and the warheads produced use a mix of 'factory' produced components and custom-made components as production equipment is finalised. It is probable that it was one of the warheads built during the first phase that failed to achieve a large fraction of its design yield.

A conservative analysis reveals that, at the very least, 70 per cent of the W-76s should detonate as planned. This is a worst-case scenario.

By correlating publicly announced tests and the known periods of warhead development, there have been at least eight full-yield detonations of the W-76 warhead during and after development. From this, statistical laws set strict limits on how many defective warheads could be in the US stockpile. A conservative analysis reveals that, at the very least, 70 per cent of the W-76s should detonate as planned. This is a worst-case scenario. The true percentage of weapons performing as planned would be considerably greater than this. If, as many tactical analysts believe, multiple warheads would be fired at each target, then more than 90 per cent of the targets would be destroyed.

Probability of defects

Some critics claim that the number of tests conducted limits the accuracy of the measured distribution of explosive power. Some might further claim that it was pure luck that the tested warheads did not suffer from instabilities and, if more had been tested, then this fatal flaw would have been detected. Statistics, however, can allow us to put an upper limit on how much of this could be an underestimate.

Weapons designers at Los Alamos and Lawrence Livermore national laboratories have considerably more information about each nuclear test than can be derived from sources available to the public. Tests that measure emitted x-rays, neutrons and other radioactive particles, to name just a few of the many diagnostics, can be used to precisely check how different parts of the warhead are performing.

Probably the crudest such measurement of testing is to compare the measured yield to the design yield. Taking a very conservative example of 10 per cent for the fluctuations around the W-76's 100 kT design yield, a confident estimate suggests that 95 per cent of the warheads would detonate with yields greater than 60 kT — assuming that the weaponeers were extremely unfortunate in their search for duds by picking only high-yield warheads to test. At a 60 kT yield, there is only a 10 per cent decrease in the warhead's effective kill-radius for hardened silos. So, no matter how cautious the assessment, the W-76 remains a reliable component of the US nuclear deterrent.

How does this correspond to the warhead's utility? It depends on what is being targeted. First, consider the W-76 is being used as a retaliatory, second strike weapon by attacking population centres. In this case, 95 per cent of the design-strength warheads would destroy all the buildings within 5.5 km of its aim point and create fire and destruction considerably further away. In the worst-case scenario mentioned above where there is the potential for Rayleigh-Taylor instabilities affecting the warhead, then the same fraction of warheads have only a 17 per cent reduction in killing range.

If, on the other hand, the W-76s were targeted against hard targets, such as missile silos that require 2,000 pounds per square inch (psi) over pressure to destroy, there is only a 10 per cent reduction in killing range from roughly 200 m to 180 m. Furthermore, this lower range is still considerably greater than the estimated 90 m-radius accuracy of the Trident II missile. Even in the worst-case scenario imagined here, the W-76 would remain an effective counterforce weapon.

Still, critics of the W-76 might claim that the Rayleigh-Taylor instability is too unpredictable to show up in any of the test data collected. While such a claim seems very improbable, it cannot be discounted without access to the sophisticated models and test data available to the weapons laboratories. Nevertheless, the first analysis presented here still remains: given the estimated eight tests of the full W-76, at the very least 70 per cent of them should detonate with their design yield. That reliability is great enough to retain confidence in this important component of the US nuclear deterrent. •

Author

Geoff Forden is a research physicist in MIT's Program on Science, Technology, and Society and was Chief of Multidisciplinary Analysis at UNMOVIC, the UN arms inspection agency for Iraq.