
How Much Reliability and Yield Is Enough for a CTBT?

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This year the United States Senate will be asked for its advice and consent on the Comprehensive Test Ban Treaty (CTBT). Since *Physics and Society* has already had several papers [1] on the CTBT, I will confine this paper to the single issue of "how much reliability and yield is necessary to maintain a vibrant deterrent for a strong national security." Rather than give descriptive arguments, this paper will be confined to a sensitivity analysis of some parameters. It is important to carry out such an analysis because those who will oppose ratification will raise the specter of potential declining yields and reduced reliabilities of nuclear weapons.

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Since the U.S. and Russia have conducted 85 percent of the nuclear tests, one would expect that these two nations have an advantage over the other nations on the physics of nuclear explosions. Now that Russia's nuclear infrastructure is collapsing, the U.S. will retain a large lead in testing knowledge from its 1000 tests. Under START II, the U.S. will retain 10,000 warheads with 3500 of them deployed for strategic use and another 1000 for a somewhat slower response. These forces are considerable and stable with respect to the unlikely possibility of a worst-case attack by Russia.

Some of the unanimous conclusions from the JASON study on nuclear testing [2] by 14 prominent scientists, including four DOE weapon designers, are as follows: The JASON group concluded that they have a high confidence in the safety, reliability, and performance margins of the present U.S. nuclear stockpile which will continue to be needed for deterrence. In addition they concluded that the U.S. can maintain the

quality of its nuclear weapons with the Science-Based Stockpile Stewardship and Management Program which does not include nuclear testing. The group concluded that the range of performance margins of the weapons are adequate at this time and that past problems were primarily the result of incomplete or inadequate design activities. The JASON group is convinced that those problems have been corrected and that the weapon types in the enduring stockpile are safe and reliable in the context of explicit military requirements.

DOE's definition of reliability is concerned with the "ability of an item to perform a required function...." implicit in the above definition of 'ability' is the concept of successful performance. Successful performance for nuclear weapons is defined as detonation at the desired yield (or higher) at the target...." A strict reading of this definition requires the verdict of "unreliable" for a Trident II D5 W88 warhead which had a yield of 428 kilotons, 10% below the reported design yield of 475 kilotons. Since modest reductions in yield and reliability would make rather minor reductions in the two-warhead-attack mode, one should not conclude that these warheads are unreliable without considering the mission of the weapons.

Variations in Yield: The JASON group, the DOE laboratory directors, and the Joint Chiefs of Staff have evaluated the stock pile as reliable and safe. Nevertheless, how important would a reduction in yield be? In order to answer this question, we can estimate the probability that a warhead can destroy a target, P_k , with the approximate formula [3];

$$P_k = R [1 - (1/2) - (E Y / CEP^3 H)^{2/3}] \quad (\text{Eq. 1})$$

where Y is the yield in megatons, H is the target hardness in psi, CEP is the circular error probable accuracy in nautical miles and R is the fractional reliability. The constant E has a value of 16.4 nmi³psi/Mt. The probability of kill for multiple warheads against a target is

$$P_k(n) = 1 - [1 - P_k]^n \quad (\text{Eq. 2})$$

The following parameters [4] can be used to describe U.S. systems:

	Yield	Accuracy (CEP)
PK (MX)	0.3 Mtons	0.05 nautical miles
Trident D5	0.475 Mtons	0.06 nautical miles
MMIII	0.335 Mtons	0.12 nautical miles (CEP to be improved)

The reliability is assumed [5] to be 90%. For the case of very hard targets of 5000 psi, a very large reduction of 50% in yield reduces $P_k(2)$ for Trident D5 from 97.3% to 92.6% and for the Peacekeeper from 97.6% to 93.5%, or a reduction of only 4.5%. For the case of hardened silos of 2000 psi, Trident $P_k(2)$ is reduced from 98.9% to 98.0% and for the MX from 98.4% to 98.2%, for an average reduction of 0.5%. From these results it is clear that very large reductions in the performance yield are not critical. Using values of $H = 5000$ psi for very hard targets and $R = 0.9$, we obtain Fig. 1 which gives the probability of kill for two warheads on a silo, $P_k(2)$, as a function of the fraction of full yield. We note that this curve is only slightly changed for 50% reductions in yield for our two most potent systems, the Peacekeeper and Trident D5 W88.

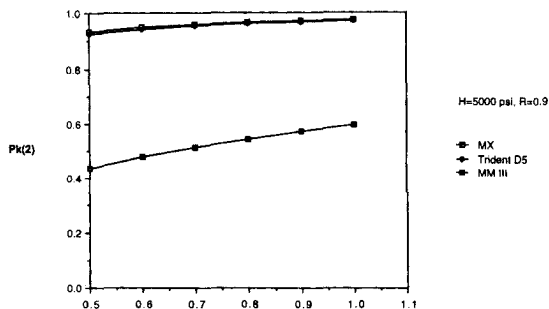


Fig. 1. The two-shot kill probability vs. the fractional performance yield of three U.S. systems. ($H = 5000$ psi, $R = 0.9$)

Reduced Reliability: The reduction in kill probability from reduced reliability of two warheads attacking a hard target can be estimated in a similar fashion. For a 20% reduction in the assumed reliability of 90% against the 5000 psi silos, the $P_k(2)$ kill probability for the Trident is reduced from 97% to 89%, and for the Peacekeeper it is reduced from 98% to 89%, for an average reduction of 8%. A vast reduction of 50% in reliability reduces the kill probabilities by 32%. The $P_k(2)$ kill probability as a function of the fractional reliability is plotted in Figure 2.

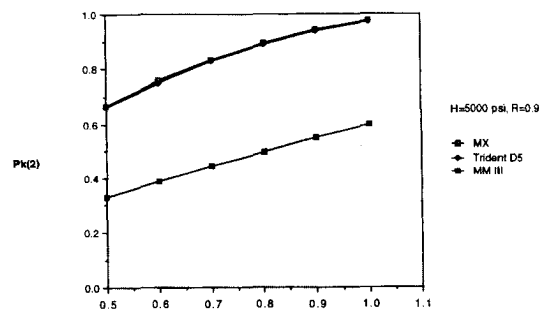


Fig. 2. The two-shot kill probability $P_k(2)$ vs. the fraction of assumed reliability. ($H = 5000$ psi, $R = 0.9$)

Conclusion: On February 7, 1997, Secretary of Defense William Cohen and Acting Secretary of Energy Charles Curtis delivered the annual Nuclear Stockpile Certification:

"In response to Presidential direction to conduct an annual certification of the nuclear weapons stockpile, we have thoroughly reviewed the stockpile and judge it to be safe and reliable. There is no need to conduct an underground test at this time. Problems that have arisen in the stockpile, for example as a result of aging components, are being addressed to assure the stockpile remains safe and reliable. These current problems can be resolved without nuclear testing. In reaching this conclusion, we have obtained the advice of the Directors of DOE's Nuclear Weapons Laboratories, the Commander-in-Chief, Strategic Command, the Chairman of the Joint Chiefs of Staff, and the Nuclear Weapons Council."

The annual certification process involved calculations and considerations much beyond the estimates given here. However, some of the concepts of this paper must have been part of the certification process. Because the mission must be considered along with the properties of the warhead, it is necessary that both the Secretaries of Defense and Energy, acting together, made the certification. If this were not the case, the Secretary of Energy could claim problems with reliability or yield that did not meaningfully affect the mission. As a reality check, we should remember that deterrence is a psychological concept based on the perceptions of other countries that our systems indeed are reliable and have considerable yield. The message of this paper is that the mission for the weapons must be considered along with the performance status of the warheads, and the U.S. has a considerable excess of survivable yield and reliability for the prescribed missions.

References:

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2. Nuclear Testing, Jason Report #JSR-95-320, Mitre Corp., McLean, VA, Aug. 3, 1995.
3. D. Hafemeister, p. 44-62 in Arms Control Verification, ed. by K. Tsipis, D. Hafemeister and P. Janeway, Pergamon-Brassey, Washington, 1986. S. Fetter, Toward a Comprehensive Test Ban, Ballinger, Cambridge, MA, 1988.
4. The Military Balance, International Institute of Strategic Studies, London, 1994.
5. U.S. Congressional Budget Office, The START Treaty and Beyond, 1991.

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