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The Future of Nuclear-weapons Testing

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Frank von Hippel -- Biographical Data

Frank von Hippel, a physicist by training, is a Professor of Public and International Affairs at Princeton University and co-principal investigator with Harold Feiveson of Princeton's Program on Nuclear Policy Alternatives. He is also chairman of the research arm of the Federation of American Scientists (FAS), directs the FAS cooperative research project on the technical basis for new arms-control initiatives, and chairs the editorial boards of *Science & Global Security* and the *Bulletin of the Atomic Scientists*.

von Hippel received his B.S. degree in physics from MIT in 1959 and D.Phil. in theoretical physics in 1962 from Oxford, where he was a Rhodes Scholar. During the following ten years, while his research focus was in theoretical elementary-particle physics, he held research positions at the University of Chicago, Cornell University and Argonne National Laboratory and served on the physics faculty of Stanford University.

In 1974, von Hippel's interests shifted to "policy physics." After spending a year as a Resident Fellow at the National Academy of Science, during which time he organized the American Physical Society's Study on Light-water Reactor Safety, he was invited to join the research and then the teaching faculty of Princeton University.

During the late 1970's, von Hippel's research focused on technical questions relating to the containment and mitigation of nuclear-reactor accidents, alternatives to recycling plutonium in nuclear-reactor fuel, and the potential for major improvements in automobile fuel economy. For the past decade, his research has focused on the possibilities of: deep cuts in the nuclear arsenals, verified nuclear-warhead elimination, a universal cutoff of the production of unsafeguarded fissile materials and a low-threshold or comprehensive nuclear-warhead test ban.

von Hippel has served on advisory panels to the Congressional Office of Technology Assessment, U.S. Department of Energy, National Science Foundation and U.S. Nuclear Regulatory Commission and on the Boards of Directors of the American Association for the Advancement of Science, Federation of American Scientists (chairman) and Bulletin of the Atomic Scientists.

In 1977, he shared with Joel Primack the American Physical Society's 1977 Forum Award for Promoting the Understanding of the Relationship of Physics and Society for their book, *Advice and Dissent: Scientists in the Political Arena*. In 1989, he was awarded the Federation of American Scientists' Public Service Award. In 1991, the American Institute of Physics published a volume of von Hippel's selected works as one of the first three books in its "Masters of Physics" series under the title, *Citizen Scientist*.

New Priorities

The end of the Cold War has had a profound impact on the arguments for and against testing.

The opponents to a Comprehensive Test Ban have shifted their emphasis from verifiability and then the need to maintain warhead reliability to the need to keep testing in order to make our nuclear weapons more safe and secure.

And the test-ban proponents have shifted their emphasis from the need to prevent the development of destabilizing first-strike weapons to the importance of a universal Comprehensive Test Ban to a strengthened nonproliferation regime.

In the remainder of my statement, I explore first the arguments connecting testing to nuclear-warhead safety, security and reliability and then the connection between a CTB and nonproliferation.

Testing and Warhead Safety

If you read the most recent mission statements of the weapons laboratories, you will see that they have embraced the development of "inherently-safe" nuclear-warhead designs as a central rationale for the maintenance and even growth of their nuclear-warhead development programs. Los Alamos proposes an approximately constant annual budget for nuclear-warhead research, development and testing of about one third of a billion dollars despite the cancellation of virtually all nuclear-warhead development programs and Livermore proposes an *increase* by 50 percent, to half a billion dollars a year and a 40 percent increase in personnel relative to the levels of fiscal year 1991.[1]

However, nuclear disarmament in the form of the INF and START treaties and President Bush's 27 September unilateral initiatives are already eliminating the older less safe nuclear-warhead designs from the U.S. nuclear arsenal. And the withdrawal to storage of U.S. warheads formerly deployed on ships, in Europe and on alert bombers has greatly reduced the exposure to accident of the remaining warheads.

As I will explain below, by going through the different classes of warhead accidents, starting with the most serious, the development of "inherently safe" nuclear-warhead designs would make only a relatively minor further additional contribution to warhead safety beyond what can be achieved by with other more conventional approaches. In this section

of my testimony, I depend heavily on the excellent reports to Congress by Dr. Ray Kidder of the Livermore National Laboratory.*

Accidental nuclear explosion. Protection against accidental nuclear explosions is currently built into modern nuclear warheads with enhanced electrical isolation (EEI) and one-point safety.** If there is any doubt about one-point safety or there is a requirement for multi-point safety, a warhead can be made mechanically incapable of a nuclear explosion by, for example, having a wire in the hollow plutonium core which is only withdrawn when the warhead is armed. This type of mechanical safing can be added to a warhead without nuclear testing and has been "in successful use for more than 20 years."[2]

Of course, you can also design a mechanical safing arrangement that requires a radical redesign of the whole warhead and therefore a lot of nuclear testing. This is the approach with "inherently-safe" nuclear-warhead designs that would keep the plutonium and the chemical explosive separate in an unarmed warhead. However, such a design does not have any obvious advantages *with regard to nuclear-explosion safety* over types of mechanical safing that do not require testing.

Detonation of the chemical explosive. The less serious class of nuclear-warhead accidents would involve the detonation of the chemical explosives in the warheads without nuclear yield but creating a highly carcinogenic aerosol of plutonium oxide. This risk has been reduced to very low levels in most modern nuclear-warhead designs by the use of insensitive high explosives (IHE). Thanks to the recent nuclear reduction decisions, all but three of the older designs containing insensitive high explosives are being retired (see Table 1). To convert the remaining three would require less than ten tests:[3]

- The W-88 and W-79 warheads on Trident II submarine-launched ballistic missiles could be replaced by the W89. Dr. Kidder estimates that two nuclear tests would be required to complete the development of the W89: one to check the warhead performance in a reentry vehicle package and a second to check the production

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* R.E. Kidder: *Report to Congress: Assessment of the Safety of U.S. Nuclear Weapons and Related Test Requirements* (Lawrence Livermore National Laboratory report # UCRL-LR-107454, July 1991); *Assessment of the Safety of U.S. Nuclear Weapons and Related Nuclear Test Requirements: A Post-Bush Initiative Update* (Lawrence Livermore National Laboratory report # UCRL-LR-109503, December 1991).

** The warhead is designed so that a significant nuclear yield (greater than 4 pounds of TNT equivalent) will not result if a detonation is initiated in the chemical explosive at only a single point.

model. If pit fabrication is not resumed, a third test would be required to test the design with a recycled pit.

- If the MX is retired and the Minuteman III deMIRVed, as proposed by President Bush on 28 January, then an adequate number of MX W87 warheads would become available to replace the Minuteman III W78 warheads.

- Kidder estimates that developing a new warhead incorporating IHE to replace the Trident I W76 warhead would require 4 tests.[4] Alternatively, the Trident I missiles could be replaced by Trident II's equipped with W89's.

In the unlikely event that Congress decides that we need an earth-penetrating warhead for cruise missiles, or five instead of two variants of the B-61 tactical bomb in our stockpile, a few additional tests would be required.

To my knowledge, the Navy has shown little interest in replacing either the W88 or W76 Trident warheads with a warhead containing IHE. Professor Steve Fetter of the University of Maryland and I undertook to calculate the consequences if several Trident I warheads exploded at the Bangor Trident Submarine Base converting a total of 10 kilograms of plutonium into a fine inhalable aerosol and the wind blew the aerosol toward Seattle. We found that, depending upon the weather conditions and the carcinogenicity of inhaled plutonium, anywhere from 20 to 2000 additional cancer deaths might result over the following decades. (The average extra individual risk would be on the order of one in one thousand.)[5]

This would indeed be a serious accident. Some argue, however, that the probability is already so low that we could save more lives by spending the money on other problems. I do not have a strong opinion either way. However, if we are to have a comprehensive test ban by 1995, as many advocate, a final decision on whether or not to develop additional warhead designs containing IHE will have to be made soon. As the Drell panel suggested, an additional level of protection could also be achieved by replacing the propellant of the Trident missiles with non-detonable 1.3 class propellant.[6]

Separating the plutonium from the high-explosive in the warhead by armor, as proposed for "inherently safe" designs, could reduce the risk still further. However, if the great reduction of risk that can be achieved by shifting the remaining warheads over to IHE is considered marginal by the Administration, it is hard to imagine the cost-benefit calculation that has led it to conclude that it is worthwhile to invest many billions on an open-ended attempt to develop warhead designs that would reduce the hazard still further. I can only conclude that, at this point, the Administration's anti-testing position is on ideology rather than analysis.

Fire. Finally, there is the possibility of some local contamination by plutonium if a warhead is consumed in a fire without the chemical explosive detonating. However, this would be a relatively minor accident. According to the Drell report, the area that might be contaminated would be on the order of 1 km^2 versus 100 km^2 for a chemical-detonation accident. Furthermore, the particle sizes of the plutonium ash would tend to be of larger than inhalable size. The Drell panel recommended that all bomber-carried warheads have fire-resistant pits able to keep the plutonium contained in a jet-fuel fire. The plutonium components in separable component warheads could potentially be made even more fire resistant. But the accidents involved are not that severe and their probability will be *very* low after completion of the removal of nuclear warheads from alert bombers, naval ships and foreign bases.

Testing and Warhead Security

The need to improve warhead security is sometimes also mentioned as a reason to continue to test indefinitely. But, here again, the problem appears quite finite. Indeed, the problem warheads appear to be same Trident warheads because the Navy ordered them without permissive-action links (PALs) as well as without IHE. Decisions about the replacement of these warheads should therefore take into account the desirability of *all* warheads being equipped with PALs. (The W-80-0 warhead for the Navy's sea-launched cruise missile is not equipped with a PAL but presumably could be retrofitted without a nuclear test being required since it is closely related to the W-80-1 on the Air Force's air-launched cruise missile, which has a PAL [category D].)[7]

Reliability

The ultimate argument used by opponents of a Comprehensive Test Ban is the need to preserve the "competence" of nuclear-weapon experts. The concern is that expertise will decline over a period of decades and that the weapons laboratories will become less reliable advisors on the sensitivity of warhead performance to small variations in warhead construction when the time comes to remanufacture them. However, the original documentation of warhead designs contains information on manufacturing tolerances and, based on the historical record, such information appears to be adequate. According to Dr. Kidder's 1987 report to Congress on warhead reliability, at that time, only once since stockpile confidence tests began in 1979 had the first test of a nuclear warhead in its actual stockpile configuration produced a yield significantly lower than expected. Apparently, in this case (the W84) a number of "uncalculable" engineering changes were made between the development tests and the actual stockpile configuration.[8] Obviously such changes would not be permitted if warheads were being reproduced in

an environment where testing were no longer an option. The classified version of Dr. Kidder's report apparently contains a great deal of additional historical data that supports his conclusion that testing is not required to sustain the reliability of previously well-tested designs remanufactured to original standards.

The weapons laboratories sometimes argue that it may not be possible in the future to remanufacture weapons using the same materials and components that are available today. However, it would certainly be less expensive to ensure that such materials and components will remain available as long as they are needed than to continue to test indefinitely.

Nuclear testing and Nonproliferation

There are a number of reasons to believe that a comprehensive test ban would strengthen the nonproliferation regime. I will limit myself to two here: 1) the possibility of a revival of interest in "peaceful" nuclear explosions, and 2) nonproliferation politics.

"Peaceful" Nuclear Explosions. The U.S. nuclear-weapons establishment originally launched its "Ploughshares" program in the late 1950s in part out of opposition to a test ban treaty. The program was limited and ultimately ended after 15 years because the cost advantages of using nuclear explosives appeared to be outweighed by public concern about the radioactive environmental contamination that they left behind.

However, PNEs continued to complicate the non-proliferation as well as the arms-control agenda. Recall that India's nuclear test in 1974 was of a "peaceful nuclear explosive" and that Brazil and Argentina for many years reserved to themselves the right to develop PNEs even though they had signed the Treaty of Tlateloco, which bans the introduction of nuclear weapons into Latin America.

Because of the superior ability of the Soviet government to override public opinion, the PNE program went further in the USSR than in the U.S. However, with the rise of the democracy movement there during the 1980's it died too.

Thus we find ourselves in a window during which there is no on-going PNE program anywhere in world. However, there is no reason to believe that this will continue for long. Indeed, with its nuclear-weapons-testing program shut down, Arzamas-16, one of the Russian nuclear-weapons laboratories -- backed by Yeltsin's new Minister of Nuclear Power, Victor Mikhailov -- is pushing very hard to gain acceptance for a very ambitious peaceful nuclear explosions programs. According to their proposal, PNEs are the best way to eliminate both chemical and radioactive wastes -- starting with chemical weapons and the surplus plutonium pits from nuclear weapons. And, of course, the

infamous international Chetek corporation wants to market a toxic waste disposal service using PNEs for hard currency. If this project gets off the ground, it could relegitimize PNE programs worldwide.

On the other hand, if we ban the testing of nuclear warheads, it has become clear that we will be banning PNEs as well because there is no way to tell the difference. We have already seen this in the fact that the 150-kt Threshold Test Ban Treaty of 1974 was not considered viable until it was supported by the Peaceful Nuclear Explosions Treaty of 1976 which bans PNEs above 150 kt. Similarly, when the Carter Administration was negotiating a Comprehensive Test Ban in the late 1970's, it insisted on -- and obtained a Soviet commitment to -- an accompanying moratorium on PNEs.

If we do not want to go around on the PNE merry-go-round once again, therefore, this would be a good time to stop blocking the worldwide movement for a CTB.

Nonproliferation Politics. I am not one of those who believes that a failure of the U.S. to commit to a Comprehensive Test Ban (CTB) will block renewal of the Nonproliferation Treaty (NPT) in 1995. However, I believe that a failure of the U.S. to commit to a CTB will undermine our ability to *strengthen* the nonproliferation regime. We saw this at the 1990 NPT Review Conference, when the refusal by the U.S. and U.K. to commit to the goal of a Comprehensive Test Ban blocked a final statement that included an agreement not to export nuclear technology to countries that do not accept safeguards equivalent to those accepted by non-nuclear weapons states signatories to the NPT.

In the NPT, the nuclear-weapons states committed themselves to:

> "pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament" (Article VI) and, in particular, "to achieve the discontinuance of all test explosions of nuclear weapons for all time and to continue negotiations to this end" (preamble).

The discontinuance of nuclear testing is seen worldwide as a first step toward the a world of zero nuclear weapons. This is the only way to understand the fact that 41 signatories to the Partial Test Ban Treaty called for the unprecedented conference to discuss amending the Partial Test Ban into a CTB that was held at the U.N. during January 1991. Ninety seven nations sent delegations and, after the U.S. and U.K. promised to veto any amendment, voted 75 to 2 with 19 abstentions to meet and try again. Although this event went without much public notice because it coincided with the beginning of the Gulf War, it gave an important indication of the views of other countries on the desirability of a CTB.

The nonproliferation regime is not viable in the long term without a world of zero nuclear weapons as its ultimate goal -- even if only at a far future date that is today not foreseeable. If we insist that nuclear weapons are forever, then, over time, more and more countries will argue that they too need such weapons. There is no objective way to divide the countries in the world into those that need nuclear arms and those that do not.

We might try to explain to the world that we are no longer testing to develop new types of warheads -- just making safer and more secure what we have. Certainly that would be a step in the right direction if that were established as national policy.* However, we should only try to sell such a posture if we believe that indefinitely continued nuclear weapons testing is really required for these purposes. As I have explained above, I believe that it is not.

Many will argue in this cynical town that notions of equity and universal bans are irrelevant. In the real world nations act according to their own selfish interests. But, as Sakharov and many others have shown us, ideals can have great political power *in the longer term*. And nonproliferation is a long-term problem.

I have studied the nonproliferation success stories in Sweden -- which had a nuclear-weapons program in the late 1960's -- and in Brazil and Argentina. In each case, it was not the security establishment that calculated that nuclear weapons were not in the national interest. They wanted nuclear weapons! It was a citizen's movement that saw nuclear weapons as illegitimate and forced the government to shut down its weapon program. In Sweden it was the women's movement of the Social Democratic party. In Brazil and Argentina, university physicists took the lead.

Similarly, in the former Soviet Union, it was a Kazakh citizen's movement led by a poet that shut down the Soviet test program.

The U.S. government seriously undermines such movements by telling them that, after almost 1000 tests in almost 50 years, we still cannot make a commitment to stop at a time definite.

Ultimately, the question that we may have to answer is this: "What is more important to our security: the worldwide anti-nuclear-weapon movement or testing?" The Reagan and Bush Administrations voted for testing. Strong Congressional support for the Gephart nuclear-test-moratorium act would give the world reason to hope that this is not

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* In its *Institutional Plan for FY 1992-97*, Los Alamos states that "the Laboratory will study new weapon concepts (e.g. earth-penetrating weapons, highly accurate small yield weapons, anti-materiel, and anti-CBW weapons)" (p.7) and "enhanced electromagnetic pulse weapons" (p. 22).

our last word.

Table 1. U.S. Nuclear Warheads[a]

Warhead	Weapon System	Entered Stockpile	Safety Features[b]
Under development			
W89	SRAM-A? (2-3 tests req.)		EEI, IHE, FRP
W61	cruise-missile earth penetrator		EEI, IHE
B61-6,8,9	Tac. bombs (replacements for B-61-0,2,5?)		EEI, IHE
In stockpile			
B61-10	tactical bomb	1990	EEI, IHE
B61-7	strategic bomb	1986	EEI, IHE
B61-3,4	tactical bombs	1980	EEI, IHE
W88[c]	Trident II SLBM	1990	EEI
W87	MX ICBM	1986	EEI, IHE, FRP
W80-0	Sea-launched cruise missile	1984	EEI, IHE
B83	Strategic bomb	1983	EEI, IHE, FRP
W-80-1	Air-launched cruise missile	1982	EEI, IHE
W78[c]	Minuteman III	1980	EEI
W76	Trident I,II SLBMs	1979	EEI
Retired or Being retired			
W68	Poseidon	1970 by START Treaty	--
W62	Minuteman III	1968 "	--
W56-4	Minuteman II	1968 "	partial EEI
W70-1,2,3	Lance miss.	1973-81 Bush 27 Sept. 91	--
W79	Artil. shell	1980 "	--
W48	Artil. shell	1963 "	--
W33	Artil. shell	1956 "	--
B-57-1,2	Depth bomb	1963 "	--
W84	GL cruise miss.	1983 INF Treaty	EEI, IHE, FRP
W85	Pershing II	1983 "	EEI, IHE
W50	Pershing IA	1963 "	--
W71	Spartan ABM	1975 ABM Treaty	--
W69	SRAM-A	1972 Being replaced	--
B53-1	Strat. bomb	1988 "	partial EEI
B28-0,1	Strat. bomb	1983 "	partial EEI
B61-5	Tac. bomb	1977 "	EEI
B61-2	"	1976 "	--
B61-0	"	1968 "	--
B43	Tac. bomb	1961 "	--

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[a] Based on R.E. Kidder, *Reports to Congress*, July 1991 and December 1991.

[b] EEI = enhanced electrical isolation, IHE = insensitive high explosive. FRP = fire-resistant pit.

[c] The W-88 and W-76 on the Trident II could be replaced by the W-89. The W78 could be replaced by W87 if the Minuteman III is downloaded to one warhead, as proposed by President Bush on 28 January 1991.

References and Notes

1. *Los Alamos National Laboratory Institutional Plan: FY 1992-1997*, table XI-4; Lawrence Livermore National Laboratory, *Institutional Plan: FY 1992-1997*, Table A-5.

2. R.E. Kidder, *Assessment of the Safety of U.S. Nuclear Weapons and Related Nuclear Test Requirements: A Post-Bush Initiative Update*, B-1.

3. R.E. Kidder, *Assessment of the Safety of U.S. Nuclear Weapons and Related Nuclear Test Requirements: A Post-Bush Initiative Update*, B-1.

4. R.E. Kidder, *Assessment of the Safety of U.S. Nuclear Weapons and Related Nuclear Test Requirements: A Post-Bush Initiative Update*, Table 1.

5. Steve Fetter and Frank von Hippel, "The Hazard from Plutonium Dispersal by Nuclear-warhead Accidents," *Science & Global Security 2* (1990), pp. 21-41.

6. *Nuclear Weapons Safety*, Report of the Panel on Nuclear Weapons Safety of the House Committee on Armed Services, December 1990., p. 29.

7. In any case, only category-F PALS are so integrated into nuclear warheads that a nuclear test is required to determine their effect on warhead performance. Category-F PALS are reportedly installed in the B61 tactical bomb (mods 3 and 4), the W-85 (Pershing II) warhead and the W-84 (ground-launched cruise missile) warheads. These warheads were (and presumably still are in the case of the B-61) deployed at foreign bases. [This discussion of PALs is based on "Nuclear Notebook," *Bulletin of the Atomic Scientists*, June 1990, p. 48; Steve Fetter, *Toward a Comprehensive Test Ban* (Cambridge: Ballinger Publishing Co., 1988), p. 37; and Thomas B. Cochran, William M. Arkin and Milton M. Hoenig, *U.S. Nuclear Forces and Capabilities* (Cambridge: Ballinger Publishing Co., 1984).

8. R.E. Kidder, *Maintaining the U.S. Stockpile of Nuclear Weapons During a Low-Threshold or Comprehensive Test Ban* (Lawrence Livermore National Laboratory report # UCRL-53820, 1987).