Hydronuclear Testing and the Comprehensive Test Ban: Memorandum to Participants JASON 1994 Summer Study

by

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EXECUTIVE SUMMARY

Although no commonly accepted definition exists, a "hydronuclear test" may be generally described as a nuclear weapons test, or high-explosive driven criticality experiment, characterized by a nuclear energy release that is insufficient to heat the core material to the plasma temperatures that would cause it to explode "like a bomb." In such a test, the TNT equivalent energy release from fission would therefore not exceed the amount released by the chemical high explosive used to compress the fissile material, and could be considerably less. Nuclear-weapon states, and possibly other states, also perform high-explosive driven implosion experiments using fusion material, although these are not normally characterized as "hydronuclear tests".

Hydronuclear tests can serve a useful role in the development of the full spectrum of unboosted fission weapons, including first generation nuclear weapons of the implosion type with yields in the 5 to 30 kiloton range, more sophisticated designs with yields up to about a megaton, and advanced micro-nuclear weapons with yields of 5 to 500 tons. For pure fission weapons hydronuclear tests can be used to:

* optimize the timing of initiation of the chain reaction,
* optimize the yield-to-weight ratio,
* optimize the yield-to-volume ratio,
* predict more accurately the minimum yield of a nuclear device even if ones weapon codes are not adequately calibrated with regard to the disassembly phase,
* predict more accurately the actual yield of a nuclear device provided ones weapon codes are adequately calibrated with regard to the disassembly phase,
* improve equation-of-state data relating the pressure, temperature and densities of materials at high pressures
* confirm the history of α prior to disassembly,
* confirm the neutronic behavior at the center of the core where the densities are highest and the uncertainties are greatest,
* confirm the neutronic behavior of the materials surrounding the core, e.g, high explosive, flying plate, reflector/tamper, during the initial assembly phase of the chain reaction,
* confirm safety aspects of a weapon through single point detonations.

Since hydronuclear tests do not generate sufficient yield to create the conditions for substantial fusion of deuterium and tritium in the core, such tests do not provide a reliable means for extrapolating the performance of new ''boosted'' fission weapons and thermonuclear primaries, or thermonuclear secondaries.

However, the output of 14 Mev neutrons from high-explosive driven implosion experiments using small quantities of fusion material does provide a sensitive barometer of the symmetry achieved in the convergent shock wave generated by the implosion mechanism. Thus such tests could be useful for the development of higher-yield fission weapons.

In negotiating the Comprehensive Test Ban Treaty (CTBT) the current approach of the U.S. Government, and many other governments, is not to seek further definition in the treaty text of the basic CTB obligation not to conduct a "nuclear weapons test explosion, or any other nuclear explosion." Instead, the U.S. government and other nuclear weapon states are seeking to preserve their ability to conduct very low yield tests by negotiating a common understanding among themselves regarding the scope of so-called "treaty compliant" activities. This common understanding would then be read into the negotiating record by the Chairman of the Conference as the putatively "authoritative" interpretation of the treaty's scope.

The exact legal status of such a joint statement, and its ultimate force and effect on other treaty parties, remain to be determined. To date, the nuclear-weapon states remain far apart in their respective conceptions of permissible low-yield testing. Even if a common understanding could be reached, to avoid future verification difficulties and mutual suspicions of cheating, the conduct of such treaty-compliant activities must somehow be readily distinguished from those included within the scope of the treaty. While it continues to protect the right to conduct hydronuclear tests, the current U.S. negotiating position apparently does not include solutions for any of these problems.

If hydronuclear tests are permitted under a CTB, the nuclear test sites of declared nuclear powers may be maintained, in part, to facilitate the conduct of hydronuclear tests underground. Continued underground test operations at such sites, or at new sites established for this purpose, will make verification of the CTBT increasingly difficult. Undeclared nuclear weapon states and other non-NPT parties such as India, Pakistan, Israel, and Algeria will reap the advantages of a new global norm which would legally sanction nuclear weapon experimentation. The existence of such a competing global norm could undermine the prevailing interpretation of the NPT, that currently extends that treaty's prohibition on the "manufacture" of nuclear weapons to cover "preparations" for manufacture, such as hydrodynamic and hydronuclear testing. At the very least, NPT parties who may be exposed in the act of preparing or conducting such tests in the future -- as Iraq, North Korea, South Korea, and Taiwan were in the past -- will have ready-made legal justifications, based on a relatively more permissive CTB obligation, and the significant grey area that surrounds interpretation of NPT obligations as they affect nuclear research and development.

Since the marginal value of hydronuclear tests to insure the safety and reliability of existing U.S. stockpiled weapons is small in comparison to the concomitant verification complexities and proliferation risks, such tests should be explicitly banned under the CTBT, by prohibiting the release of any nuclear fission [or fusion] energy caused by the assembly or compression of fission [or fusion] material by chemical high explosive means.

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I. Introduction.

Hydronuclear tests are nuclear weapons tests, or high-explosive driven criticality experiments, limited to subcritical, or slightly supercritical neutron multiplication. As a consequence they can be designed to release negligible or at most very small amounts of fission energy. The prefix ''hydro'' means in this instance that the core of the nuclear device behaves like a fluid under compression by the chemical high explosive. Sufficient energy may be released to melt the core, but the nuclear energy released is insufficient for the core to heat to plasma temperatures and explode ''like a bomb.'' Thus, hydronuclear tests are generally limited to total nuclear energy releases, or ''yields,'' of a few kilograms or less of TNT equivalent.

There are three categories of interest for very low-yield nuclear weapon tests:

-- engineering development of new or modified nuclear warhead designs;
-- reliability assessments of existing warhead designs, and;
-- the safety of new or existing nuclear warheads.

In conducting a hydronuclear test for weapon development or reliability, some of the fissile material in the core is removed -- and perhaps replaced by non-fissile isotopes of the same element to preserve the geometry and compressional behavior of the core -- in order to radically reduce the yield of the device. Alternatively, changing the isotopic composition of the fissile component (e.g. by substituting plutonium with ≥ 85% Pu-242 for weapon-grade plutonium) or inserting neutron absorbing materials (e.g borated gas) into the hollow cores, will also achieve the desired reduction in yield. The rate of development of the chain reaction during the hydronuclear test can then be measured experimentally and the resulting data used to normalize nuclear weapon design codes for modeling development of the chain reaction in an unaltered weapon (i.e. a weapon having a full complement of fissile material of the desired isotopic mix.)

To assess the reliability of stockpiled weapons under a CTB, some analysts propose that hydronuclear tests of existing stockpiled warhead designs be conducted soon, during the current test moratorium. These test results could then serve as performance ''benchmarks,'' against which future hydronuclear test results could be compared, to gauge the effect of unforeseen physical changes or design defects in the warheads that might be discovered later.

In conducting a safety test, the full complement of fissile material can be included. The chemical high explosive is initiated at a single point, rather than simultaneously at multiple points, to demonstrate that the weapon will not explode like a bomb, should the chemical high explosive be detonated accidentally by penetration of a bullet or the shock wave of a sudden impact, but rather disassemble without producing more than a few kilograms of nuclear yield.

In Section II and III we discuss the most common types of nuclear warhead designs, to better appreciate which types require nuclear testing, and which would benefit from hydronuclear testing under a Comprehensive Test Ban (CTB). This is followed by discussions of hydronuclear testing as it relates to warhead reliability (Section IV) and safety (Section V); and then a discussion of the value of hydronuclear testing, if permitted under a CTB, in countries known to possess nuclear weapons (Section VI). In Section VII we discuss the verification implications of either banning or not banning hydronuclear testing under the CTBT. In Section VIII we argue that hydronuclear tests are within the domain of tests regulated by the 1992 "Hatfield-Exon-Mitchell" Amendment, and thus may be conducted only in compliance with the purposes, procedures, reports, and limitations imposed by this statute. Finally, we conclude that the CTB Treaty (CTBT) should ban hydronuclear testing, and we propose CTBT language that would accomplish this task.

II. Engineering Development of New Nuclear Warhead Designs.

In order to discuss which types of nuclear warheads require testing and where hydronuclear testing may be beneficial, it is useful to review the various types of warhead designs that are typically found in the arsenals of nuclear weapons states.[1] These can be categorized as either pure fission, boosted fission, or two-stage thermonuclear devices. The latter, also referred to as "fusion" or "hydrogen" weapons, are usually defined as nuclear weapons in which at least a portion of the release of energy occurs through nuclear fusion. In a strict sense, boosted fission weapons can be categorized as thermonuclear weapons since they use utilize fusion materials. However, since the fusion reaction accounts for only a small fraction of the total yield of boosted fission weapons, they are often treated as a distinct weapon category.

Thermonuclear weapons (and even fission weapons) can be categorized as having one, or more than one, stage. Single stage pure fission designs are further characterized as being either of the gun-assembly or implosion type. Multi-stage weapons are of the implosion type. The fissile core of an implosion type fission device can vary in sophistication from the low-technology *Trinity* type device -- also called a "solid pack"-- first tested by the United States in 1945, to the more sophisticated "levitated pit" design used in modern fission warheads and the fission primaries of thermonuclear warheads.

A two-stage thermonuclear weapon has a fission or boosted fission primary, also called a "trigger," and a separate component called the secondary, both contained within a heavy casing. Very high yield thermonuclear devices may have a third stage -- a tertiary. In an efficient, modern staged device, -- such as a long-range ballistic missile warhead -- the primary is likely to be boosted to conserve on volume and weight. The secondary usually contains a composite of fusion and fissile materials, although it is possible to construct secondaries from purely fissile or fusion materials. The outer casing of a staged device can be made of some type of fissionable material -- depleted, natural, or enriched uranium, or even thorium.

A. Gun-assembly pure fission designs. The simplest weapon design is the pure fission gun-assembly device. Here two subcritical masses of fissile material at normal density are brought together to form a single supercritical mass. An explosive propellent is used to fire one of the subcritical masses down a "gun barrel" into the other. Plutonium cannot be used as the fissile material because the speed of assembly is too slow to preclude a high probability of "predetonation" from spontaneous neutron emission, thereby preventing the achievement of a

[1] We do not discuss here the full spectrum of possible designs. We omit, for example, a discussion of neutron warheads and various theoretical directed energy weapon designs.

yield in excess of a few tens of tons. Therefore, gun-assembly weapons are made with high-enriched uranium (HEU), typically, uranium enriched to more than 80 percent in the isotope U-235.

The relevant physics needed to construct a workable gun-assembly weapon is widely available in the open literature, as are most of the design details of *Little Boy*, the first U.S. gun-assembly weapon. It is notable that the design of *Little Boy* predated the use of computers. *Little Boy* was not tested before it was used in combat -- at Hiroshima on August 6, 1945. Similarly, the six warhead arsenal of South Africa, since dismantled, were all gun-assembly type warheads, considerably smaller than Little Boy; and none were explosively tested.[2]

The yield of a gun-assembly device is a function of the number of critical masses of the final HEU assembly, which in turn depends on several key parameters, including the enrichment of the uranium, the type and amount of tamper/reflector material that surrounds the assembled HEU, and the geometry of the final HEU and tamper/reflector assembly. It is public knowledge that the *Little Boy* design used 64 kilograms of about 80%-enriched uranium; the target uranium was housed within a thick tungsten carbide reflector/tamper surrounded by a much thicker steel tamper; the final supercritical assembly was on the order of 2.4 critical masses; and its yield was on the order of 15 kilotons. Any country can copy this design; or if a modified design is chosen the number of critical masses of the final HEU/reflector assembly can be accurately estimated by conducting subcritical assembly measurements in the laboratory. Hence, there is no need for nuclear explosive testing to have high confidence of achieving a yield in the ten to fifteen kiloton range. While hydronuclear testing can be used in developing gun-assembly designs, the marginal value of these tests is considerably less than the value of hydronuclear testing for implosion designs.

Although the yield of the design can be predicted using modifications of commercially available nuclear hydrodynamic computer codes, there is no guarantee that the prediction would be closer than a factor of two unless one had good equation of state data and high confidence in the computer modeling. On the other hand, a simple equation relating the efficiency (i.e, the ratio of actual yield to the yield if all the fissile material were fissioned) to the number of critical masses can be derived from open sources, so computer modeling is not necessary to predict the yield of gun assembly weapons to within a factor of two or so.

B. "Solid-pack" implosion type pure fission designs. In an implosion-type fission weapon a subcritical mass of fissile material is compressed by a chemical high explosive. The fissile material is typically either plutonium, or HEU, or a composite of the two. In the most straightforward design the core of fissile material is a solid sphere or cylinder, surrounded by a reflector/tamper, which in turn is surrounded by the chemical high explosive. A sphere has the smallest surface to volume ratio, and therefore the smallest neutron losses and smallest critical mass. Other geometries can be used where the diameter of the device must be kept small

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[2] The South African bomb was reportedly 25 in. wide and 6 ft. long and weighed 2000 lbs., while Little Boy was 28 in. by 10 ft. and weighed 9000 lbs.

-- to fit, for example, in an artillery shell. To obtain a given yield, considerably less fissile material is needed for an implosion weapon than for a gun-assembly device.

Similar to the gun-assembly device, the yield of a solid-pack implosion device is a function of several factors, including the number of critical masses of the final assembly and the timing of the initiation of the chain reaction. The number of critical masses depends in turn on several other key parameters, including the size and enrichment of the fissile core, the type and amount of reflector/tamper material, and the geometry and density of the final assembly. Although the yield of the design can be predicted using modifications of commercially available nuclear hydrodynamic computer codes, accurately predicting the yield is somewhat more difficult than predicting the yield of a gun-assembly device.

On the other hand, the basic design concepts of *Fat Man* are publicly available, and any country can copy this design. As in the case of gun-type weapons, simple equations can be derived from open sources that relate efficiency to critical masses and amounts of fissile materials and chemical high explosives needed. Hence, once non-nuclear hydrodynamic testing techniques have demonstrated capabilities for rapidly compressing the fissile material to the required number of critical masses, and for initiating the chain reaction at an appropriate time, there is no need for full-scale nuclear explosive tests to provide high confidence of achieving a yield in the ten to twenty kiloton range. Hydronuclear testing could be of limited value in confirming the design and normalizing the computer calculations to predict the yield. However, if a nation's nuclear weapons program were sufficiently advanced to be conducting hydronuclear tests, it is more likely that its nuclear weapons designs would be more sophisticated than this first generation solid-pack design.

C. Levitated pit and hollow core designs. The levitated pit design is an implosion weapon where there is a gap between a "flying plate" and the fissile core. The fissile core is supported, or "levitated," in the center of the device. As described by Ted Taylor, if you want the drive a nail you do not rest the hammer on the nail and push; rather, you hit the nail with the hammer. The flying plate -- in this case a thin metal shell -- is analogous to the head of the hammer. Driven by the chemical high explosive, it gains momentum as it accelerates through the free space before striking the fissile core. By achieving greater compression, levitated pit designs can be lighter and use less fissile material to achieve the same yield, or alternatively achieve a greater yield for the same device weight.

The fissile core geometry may be solid, a hollow shell, or it may be solid fissile core levitated within a fissile shell. The flying plate can serve as the reflector tamper, part of the reflector tamper, or, as in a hollow core design, it can itself be composed of the reflector and fissile material.

The relevant physics for basic levitated pit designs is available in the open literature. Imploding hemispheric and hemicylindric flying plate systems, without the fissile materials, are used commercially to shape metals and for conducting materials research. Relative to the solid-pack nuclear warhead designs, the physics and nonnuclear experiments required to verify levitated pit and levitated core designs are more complicated, and the possibility of error is greater. Without nuclear explosive testing one could have confidence that a conservatively designed weapon would work, although one would have considerable uncertainty about its yield, and the design would not be optimal in terms of its yield-to-weight or yield-to-volume ratios. Hydronuclear tests could be used to normalize computer design codes, give greater assurance of achieving a minimum yield closer to the design yield, and optimize the design, if full-scale tests were banned under a CTB or otherwise suspended under various reciprocal unilateral moratoria or legislated constraints.

D. Boosted fission and other single-stage thermonuclear designs. As noted above, by incorporating thermonuclear fuel, typically a mixture of deuterium and tritium gas (or lithium hydrides) directly into (or proximate to) the core of fissile material, the efficiency of the fission bomb can be greatly improved; that is, one can obtain a much higher yield from a given quantity of fissile material, or alternatively, the same yield from a much smaller quantity.

Boosting is most advantageous in lower yield single-stage weapons and in the primaries of multi-stage thermonuclear weapons. High-yield single-stage designs can be made very efficient without boosting. The quantity of high explosive and fissile material in a boosted device having a yield in the few kiloton range can be made sufficiently small to be made very safe from the standpoint of single-point asymmetric detonations; that is, the yield of a single-point detonation can be made extremely small (single-point safety tests are taken up in Section V below).

Boosted fission devices are likely to incorporate many of the features of levitated pit design. Since substantial DT burning does not take place until the energy release has reached a few hundred tons of TNT equivalent, hydronuclear testing cannot provide high confidence that the boost phase of a nuclear device will operate as designed. Hydronuclear testing could provide greater confidence that the desired thermodynamic conditions required for successful boosting would be reached. A country could obtain high confidence in the reliability of a high technology boosted design by conducting a series of hydronuclear tests followed by one or more clandestine tests with a yield between 0.5 - 1 kiloton. Similarly, if a boosted primary had been previously tested in the kiloton range, hydronuclear testing could provide indirect confirmation of successful operation of the device up to a point just prior to when boosting is initiated.

E. Staged thermonuclear designs. In a staged thermonuclear device, a fraction of the X-radiation from a fission or boosted fission primary is contained within a heavy metal case. The initial X-radiation from the primary heats up the inner surface of the casing turning it into an opaque plasma. Subsequent x-radiation from the primary is absorbed by the plasma surface and re-irradiated into the cavity. Some of the radiation trapped within this blackbody cavity, also called a "hohlraum," is absorbed by the surface of the secondary component which heats up in a manner similar to the case. The radiation absorbed at the surface of the secondary causes the surface of the secondary to ablate, that is, to "boil away." The reactive force from the ablation produces a rapid compression of the secondary. The density of the secondary material, achieved by compression with radiation from a fission primary having a yield in the kiloton range, can be ten or more times greater than that achievable using chemical high explosives. Thus, the fission and fusion processes that take place in the secondary are generally much more efficient than the those that take place in the primary.

Early thermonuclear primaries of the implosion type probably had thick tampers and high yields. Since the objective is to utilize the X-radiation from the primary, in modern weapons the heavy tamper has probably been replaced by a thin beryllium reflector. This pit, now much lighter, requires much less chemical high explosive to achieve the desired compression. The lack of a heavy tamper is partially offset by the fact that the radiation that escapes from the primary does not contribute to the disassembly of the primary core. The amount of high explosive needed can be reduced even further by boosting. A typical modern thermonuclear primary might consist of a four kg plutonium core in the form of a spherical shell of 5 - 8 cm radius, a beryllium reflector and about 50 kg, more or less, of high explosive.

In a multi-stage device the secondary can be made entirely of fusion or fissionable material, or typically both. The casing can be made of fissile material (enriched uranium) or fissionable material (enriched, natural or depleted uranium, or thorium), or in the case of early British thermonuclear designs, lead bismuth.

Early conservative thermonuclear designs used heavy unboosted primaries with primary yields of a few hundred kilotons. Modern staged thermonuclear warheads use boosted fission primaries with primary yields on the order of a few to about 15 kilotons.[3]

A number of technologically advanced nations are believed to be capable of producing thermonuclear weapons without nuclear explosive tests or test data, but these are likely to be heavy single-stage devices, or possibly two-stage devices with heavy high-yield primaries. The United States and the Soviet Union produced workable, conservatively designed, multi-staged thermonuclear weapons before the advent of high speed computers. The first U.S. and Soviet and tests of two-stage thermonuclear devices were both successful. The first British two-stage thermonuclear test demonstrated staging, in that the fissile material in the secondary fissioned, but the fusion materials apparently did not burn and therefore the desired yield was not achieved. Only after the third attempt did the British achieve a successful test of a two-stage thermonuclear device. France exploded its first two-stage thermonuclear device eight and a half years and 29 tests after its first atomic test, a delay only partly accounted for by the priority assigned to development of an operational lightweight boosted fission bomb (the AN 11) for delivery by the MIRAGE IV bomber.

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[3] This estimate of the likely range of U.S. primary yields is derived from the high relative frequency of tests in the 1 -15 kt range given by R.E. Kidder, LLNL, in Proceedings of the Department of Energy Sponsored Cavity Decoupling Workshop, Pajaro Dunes, CA., 29-31 July 1985 (Washington, D.C.: DOE Report #850779) p. V-25; on Congressional testimony regarding yields required to evaluate weapon reliability, given in *Effects of a Comprehensive Test Ban Treaty on United States National Security Interests*, Hearings before the Panel on SALT and the CTB, HASC (USGPO: Washington, D.C., 1978), pp. 8 - 16; and our own calculations based on the published yield-to-weight ratio of about 0.1 kt/kg for two compact single stage fission weapons in the former stockpile -- the W33 and the W79 (see the NRDC Nuclear Weapons Databook, Vol. 1, p. 36).

China, on the other hand, successfully detonated a 3.3 Mt two-stage thermonuclear device on the first attempt, only 32 months and five tests after its first atomic test.[4] In light of this history, and given the vastly greater computing resources available today, and the unclassified advances in the scientific and engineering disciplines which bear on the design and fabrication of thermonuclear weapons, one is driven to the conclusion that a conservatively designed, staged thermonuclear design of high yield that was produced without testing would nevertheless represent a credible threat. However, perfecting the design of an optimal yield-to-weight, two-stage thermonuclear design for long range missile delivery, with a yield of several hundred kilotons, has in the past required -- and some would argue can only be achieved with -- at least partial yield testing of the secondary component. This is one of the primary technical reasons why the CTB remains an important arms control measure. Radiation implosion of the secondary and ignition of the fusion fuel of a modern staged high-yield thermonuclear weapon can be verified experimentally only with nuclear explosive testing beginning at around 10 - 20 kilotons.[5] Hydronuclear tests are of no value in this regard, since the energy of the radiation emitted from the primary is less than the energy released by the primary's chemical high explosive and is totally inadequate to compress the secondary.

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[4] R.S. Norris, et al., *Nuclear Weapons Databook, Vol.5, British French and Chinese Nuclear Weapons,* Westview Press, 1994, p. 420.

[5] J. D. Immele, "Some Issues on Thresholds and Verification," LLNL Nuclear Design Program, undated unclassified memorandum, circa January, 1987. The existence of neutron bomb designs with yields in the vicinity of 1 kiloton and the Halite/Centurion experiments with large DT capsules indicate that radiation implosion and fusion fuel burning can be explored at lesser yields.

III. The Value of Hydronuclear Tests for Engineering Development of New or Modified Nuclear Warheads.

Full-scale nuclear testing is highly desirable for all but the lowest technology designs to provide confidence in the nuclear weapon design codes, to accurately predict yields, and to optimize the designs with respect to yield-to-weight and yield-to-volume. If full-scale testing is prohibited, hydronuclear tests can serve a very useful role in the development of the full spectrum of *unboosted fission weapons*, including first generation nuclear weapons of the implosion type with yields in the 10 to 30 kiloton range, more sophisticated designs with yields of several hundred kilotons, and advanced micro-nuclear weapons that use very small quantities of plutonium and have yields less than one kiloton. For pure fission weapons hydronuclear tests can be used to:

* improve the timing of initiation of the chain reaction,
* improve the yield-to-weight ratio,
* improve the yield-to-volume ratio,
* predict more accurately the minimum yield of a nuclear device even if one's weapon codes are not adequately calibrated with regard to the disassembly phase,
* predict more accurately the actual yield of a nuclear device provided ones weapon codes are adequately calibrated with regard to the disassembly phase,
* improve equation-of-state data relating the pressure, temperature and densities of materials at high pressures,
* confirm the history of α prior to disassembly,
* confirm the neutronic behavior at the center of the core where the densities are highest and the uncertainties are greatest, and
* confirm the neutronic behavior of the materials surrounding the core, e.g, high explosive, flying plate, reflector/tamper, during the initial assembly phase of the chain reaction.

Since hydronuclear tests do not generate sufficient yield to create the conditions for significant fusion of deuterium and tritium in the core, such tests do not provide a reliable means of extrapolating the performance of new boosted fission weapons, boosted thermonuclear primaries, or advanced thermonuclear secondaries. Nevertheless, as noted above, a threshold state could obtain confidence in the reliability of high-technology boosted-fission designs by conducting hydronuclear tests followed by one or more clandestine tests with a yield of 0.5 - 1.0 kiloton. Alternatively, the hydronuclear tests could be used to achieve progress on weapons development as a contingency, in the event that the country withdraws from the CTB in the future.

IV. The Value of Hydronuclear Tests for Assessing Weapon Reliability.

Hydronuclear tests could also be conducted to assess the performance of existing stockpile weapons. These test results would then serve as benchmarks against which future hydronuclear test results could be compared. Such tests would be one way of assessing the significance of unforeseen physical changes in the warheads that might be discovered later, or of assessing the impact of possible future safety-related modifications on performance.

The marginal value of hydronuclear testing for these purposes appears to be limited. Any degradation of stockpiled weapons would be detected initially by other means, primarily by periodic disassembly and visual inspection. Degradation of the electronic arming, safing and firing mechanisms can be evaluated by testing the components independent of the nuclear assembly system. Degradation of the high explosive can be evaluated independently, and through integrated hydrodynamic testing of the implosion system with surrogate non-fissile material.

Degradation of a significant fraction of a given warhead inventory near the end of the planned stockpile life for that type would not be a serious cause for concern. The warhead type in question could be remanufactured on, or slightly ahead of schedule, to its original specifications, while accelerated aging experiments on intact weapons of the same type sought to identify the environmental exposure conditions leading to the earlier-than anticipated degradation. These experiments would presumably help to define a storage regimen that could assure the full stockpile life for the remanufactured item.

Likewise, early-to-mid life deterioration in a small number of weapons of a given class would not give rise to serious concern, if visual inspection and x-ray, ultrasonic, and other non-nuclear explosive diagnostic techniques provided a statistically valid basis for concluding that the degradation was limited to a few weapons. If the aforementioned benchmark testing had been performed, hydronuclear testing of unmodified primaries, randomly withdrawn from stockpile and injected with a borated gas to slow down the chain reaction (reduce alpha), could be a timesaving, convenient, (presumably) accurate, but also *costly* alternative method for assessing the impact of the degradation on weapon performance. However, hydronuclear testing in this instance would not be *essential*, as similar data could be obtained through traditional inspection and hydrodynamic testing techniques. Computer codes would be used to model the effects on primary yield of any observed shortcomings in hydrodynamic performance. It is by no means clear to the authors why the results of a hydronuclear test of a largely inerted primary would reveal more about the effects of degradation on performance than advanced hydrodynamic methods.

The real relevance of hydronuclear testing appears to be limited to the implausible scenario of a *large number* of weapons in a given class showing signs of deterioration *relatively early* in their stockpile life, thereby calling into question the viability of remanufacture to original specifications. If the advocates of hydronuclear testing are to be believed, hydronuclear tests of these deteriorated weapon primaries would provide a more sensitive gauge of the impact of the degradation on full yield performance than could be obtained through computations based on purely hydrodynamic testing of a primary that had been rebuilt with surrogate core materials.

If the degradation proved significant (or likely to become significant well before the end of stockpile life) hydronuclear tests of a *modified* weapon would then be compared with the original benchmark results and a judgement made as to whether the modified primary should be "recertified" for use in the original warhead system, or an entirely different warhead substituted for the defective system.

In summary, the marginal utility of hydronuclear tests is limited to those instances in which sufficient information cannot be obtained through hydrodynamic and nondestructive testing techniques, but *can be obtained* through hydronuclear testing. The future utility of hydronuclear tests for assessing weapon reliability and certifying modifications prior to remanufacture would seem to be limited to a relatively implausible conjunction of circumstances:

-- the warhead defect is in the nuclear assembly system (high explosive or fissile material);

-- the defect affects, or potentially affects, a significant fraction of a given class of weapons;

-- reasonably careful regulation of the warhead storage environment will not arrest the degradation sufficiently to permit continued stockpiling, or prevent degradation following remanufacture;

-- the defect appears relatively early in the warhead life cycle, effectively precluding remanufacture to original specifications;

-- a sufficiently precise understanding of the effects of the defect, and/or the proposed fix, on the nuclear performance of the primary system *cannot* be obtained through hydrodynamic testing alone.

-- no backup warhead system previously certified by full-scale testing exists for the delivery system(s) involved.

-- a sufficiently precise understanding of the effects of the defect, and/or the proposed fix, on the nuclear performance of the primary system *can* be obtained through hydronuclear testing.

V. Safety Assessments of Nuclear Warheads.

A safety criterion for U.S. nuclear weapons is that the accidental detonation of the chemical high explosive at a single point should not result in a fission energy release exceeding four pounds (1.8 kg) of TNT equivalent.[6] Other nuclear weapon states presumably utilize a similar criterion, albeit with perhaps higher permissible releases of nuclear energy. Whether a particular design meets the four pound criterion can be determined either by computer

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[6] DOE Order 5610.11 (paragraph 6.k) defines a "nuclear detonation" as "an energy release through a nuclear process, during a period of time on the order of one microsecond, in an amount equivalent to the energy released by the detonation of four or more pounds of TNT."

calculations, or through experimental "one-point safety" tests. Whether these one-point safety tests are included within the definition of hydronuclear tests is a matter of semantics. In any event, if hydronuclear tests are prohibited under a CTB, one-point safety tests would be excluded as well, because there are no external characteristics of either the device being tested or the energy released that distinguish the two. In the past, we estimate that the United States has conducted on the order of 130 very low yield nuclear tests for the purpose of assessing the safety of U.S. nuclear weapons.[7]

Until June 27, 1994, the United States acknowledged conducting a total of 1051 "nuclear tests" between 16 July 1945 and 23 September 1992. Of these tests, only 34 had been officially categorized by the Department of Energy (DOE) as safety experiments. All but one of these announced safety tests took place between 1955 and 1958. However, additional hydronuclear experiments were conducted by the United States during the 1958-1961 nuclear test moratorium, and the existence of these tests was not formally disclosed until the late 1980s. The total number of such experiments still has not been revealed, but a 1987 Los Alamos paper reported that during the moratorium "there were 35 hydronuclear experiments in all at Los Alamos, and a smaller number were conducted at the Nevada Test Site by the Livermore Laboratory."[8] So one may surmise that on the order of 50 such "experiments" were conducted in the 1958-61 period.

After the moratorium the only announced safety test occurred in 1988. Numerous additional safety tests undoubtedly were carried out, but they were no longer publicly identified as a separate category, and are still concealed within the broad category of so-called "weapons related" tests. Based on criteria such as minimum depth of burial, lack of seismic signature, and presence on a list of formerly secret tests that were not made public until December 1993, we estimate that another 40-50 tests could well have been conducted for weapons safety purposes from 1962 to 1992.

Some of these unannounced safety-related tests were conducted as part of multiple device events. Following the 1990 TTBT Protocol definition of a "nuclear test," the U. S. government formally defines an underground test as either a single explosion, or two or more explosions fired within 0.1 second of one another within an area delineated by a circle having a diameter of two kilometers. Usually two and sometimes three devices were emplaced in the same shaft (known as a "string of pearls") and fired simultaneously, or in rapid succession. The DOE recently declassified the number of additional devices -- 105 -- involved in such "nuclear tests with unannounced simultaneous detonations."

Modern boosted fission primaries use so little fissile material they approach inherent one-point safety -- even if a high explosive detonation is accidentally initiated at a single point, the

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[7] A June 27 1994 fax to NRDC from DOE acknowledges that 62 tests were "one-point safety experiments." We know this number to be incorrect, but because of continuing classification we do not yet know the correct total number of tests conducted for safety purposes.

[8] Robert N. Thorn and Donald R. Westervelt, "Hydronuclear Experiments," Los Alamos National Laboratory, (LA-10902-MS) February 1987, p. 6.

resulting asymmetric compression of the fissile material will release very little nuclear energy. In this regard, it should be noted that the designs that could benefit most by one-point safety tests are pure fission devices, because these devices typically require more fissile material to generate a comparable yield. Hydronuclear testing is thus most useful for modernization of a class of weapons that is now barely represented in the U.S. nuclear arsenal, but of considerable interest to proliferators. Hydronuclear testing is far less relevant to the development of boosted fission weapons generally, and the one-point safety of an adequate number of fully-tested primary designs has already been established for most, if not all foreseeable accident geometries. If required in the future, the more esoteric scenarios can be addressed by measures external to the nuclear system, rather than by further tinkering with the primary designs.

Under a CTB regime the only weapons that will be retained in the U.S. stockpile are those that will have already been fully tested and demonstrated to be one-point safe. While rare, there have been instances -- such as the W79 artillery shell and the W88 D5 missile warheads -- in which recent computer analyses indicated that a design, or the way in which it is deployed, appeared less safe than had previously been believed under certain accident scenarios. If at some time in the future, a judgement was reached that a particular warhead type was unsafe as then deployed, changing the nuclear design and conducting additional tests would not be options under a CTB. Safety concerns, nevertheless, could be resolved by mechanical safing, by substituting a safer warhead type, or by altering the manner in which the warhead is handled, stored, and deployed.

VI. The Value of Hydronuclear Testing in Specific Countries.

The value of hydronuclear testing to a weapon state under a CTB regime depends upon a number of factors, including the maturity of the states' nuclear weapons program and the extent to which full yield tests have already been conducted by, or their results disseminated to, the state in question. In this section we examine the situation in the principal countries of interest, namely those that now have nuclear warheads.

A. U.S., Russia, U.K., France and China. The nuclear weapons programs in these five declared nuclear weapons states are mature. All have deployed a variety of nuclear designs, including modern two-stage thermonuclear weapons. All have extensive nuclear test archival data.

Country	Tests	
United States	1148[9]	(24 with U.K.)
Russia	715[10]	
France	204	
United Kingdom	45	(24 with U.S.)
China	40	

All have sophisticated design codes that have been normalized against their respective tests. These codes can be used to model accurately the performance of pure fission devices during the disassembly phase, which cannot be accessed empirically via hydronuclear testing. These codes may not adequately model the boost phase of boosted designs, or thermonuclear secondaries, particularly if the designs differ radically from previously tested designs. Under a CTB regime where hydronuclear testing is permitted, hydronuclear tests would provide a highly confident basis for certifying the performance of a new generation of unboosted fission devices with yields of hundreds of kilotons, as well as a new generation of compact, highly deliverable mini- and micro-nuke weapons with yields in the tens to hundreds of tons. The U.S. is currently prohibited from further development of this latter category of weapons by an act of Congress.[11] Such a restriction may not last if the latitude to develop such weapons is afforded other nuclear weapon states under the terms of a CTB.

B. Israel. Israel has nuclear weapons and is presumed to have deployed fission weapons boosted with DT and/or lithium hydrides. Israel may have tested such a device at low yield on September 22, 1979 in the South Atlantic. There is conflicting evidence as to whether this event was a nuclear test. A White House panel concluded that the VELA sighting ''contains sufficient internal inconsistency to cast serious doubt whether that signal originated from a nuclear explosion or in fact from any light source not in the proximity of the VELA satellite.'' Israel probably has conducted numerous secret hydronuclear tests. This is well within its capability, and these could have easily gone undetected. Israel may have obtained through espionage or other means the designs of U.S. and/or French nuclear weapons and/or calibrated warhead design codes. It is widely believed that Israeli scientists were present at French nuclear

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[9] Includes 97 out of 105 recently declassified individual device detonations not previously disclosed; 8 of these were conducted for "peaceful purposes" in three group explosions under Project Plowshare for excavation or mining purposes, and thus legitimately may be counted as single "tests." The other 97 device detonations were discrete weapons R&D experiments that should be accounted for as discrete nuclear weapons tests.

[10] Does not include additional former Soviet tests that may have been part of multiple device detonations.

[11] Sec. 3136 of the National Defense Authorization Act for FY 1994 (P.L. No. 103-160, 107 Stat.1946) prohibits the Secretary of Energy from conducting "research and development which could lead to the production by the United States of a low-yield nuclear weapon which, as of the date of enactment of this Act, has not entered production.... the term 'low-yield nuclear weapon' means a nuclear weapons that has a yield of less than 5 kilotons."

tests in the Sahara during the early 1960's, and the two countries may have shared nuclear weapons design and test data. Israeli scientists have had close professional contact with scientists at the U.S. nuclear weapon laboratories in the field of nuclear technology and related sciences, and numerous Israeli scientists have participated in the physics research programs of the these laboratories.

Given Israel's apparent long experience and skill in conducting such tests, hydronuclear tests could be expected to provide Israel with nuclear design benefits exceeding those available at present to the declared nuclear powers.

C. India and Pakistan. India has exploded a nuclear device, which it termed a "Peaceful Nuclear Explosion," in 1974. Both India and Pakistan are believed to have nuclear weapons, or components that can be quickly assembled into workable weapons. There is no public evidence to suggest that either country has developed a thermonuclear capability at this time. Director of Central Intelligence William Webster, however, told a Senate Committee in May 1989 that there were indications that India was building a hydrogen bomb. Hydronuclear tests would permit India and Pakistan to improve their fission weapon designs by incorporating levitated pit and hollow core technologies. Given the high degree of tension between India and Pakistan there are ample incentives for both to improve their respective nuclear weapon capabilities, including warhead designs that would permit deployment of intermediate range ballistic missiles. Hydronuclear testing would be especially useful if either country, or both countries, decided to pursue the development of compact low-yield nuclear weapons.

VII. Verification.

While including hydronuclear tests among the tests banned under a CTBT poses a challenge to verification, this challenge is not qualitatively different from the problem of verifying other very low yield nuclear explosions, e.g. decoupled nuclear explosions with yields below about one kiloton and coupled explosions below a hundred tons. These tests cannot be readily detected and identified seismically but are universally understood to be "nuclear test explosions" falling within the scope of the treaty. Even if a seismic signature is registered for such a small event, seismology will be of little help in discriminating it from the vast background clutter of mining and other industrial explosions that occur daily worldwide. Verification of all very low-yield events will depend primarily on other national technical means and perhaps "societal verification," backed up by the codification in domestic law of the treaty's basic provisions as they apply to individuals, including criminal penalties for those found guilty of violating the provisions of such a statute.[12]

The CTBT should also include a provision that confers a protected international status upon those persons who have provided, or seek to provide, the Conference of State Parties or its Technical Secretariat with information concerning activities of a member state that may be in violation of the Treaty. Any steps taken in retaliation against such persons, their relatives,

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[12] This is already suggested by Article III.1 of the 30 March 1994 Australian Draft Text.

and associates by the government of a member state should be defined in the treaty as constituting a breach of its terms that warrants immediate referral to the Security Council.

While including hydronuclear tests within the scope of the treaty adds to the verification burden, tacitly conferring a license to conduct them also poses major verification difficulties. The term ''hydronuclear'' is a ''term of art'' -- it has no commonly understood definition. While the United States might elect to observe a limit of four pounds of fission energy release in its hydronuclear weapon tests, other countries, such as France, might observe a limit of 100 kg (i.e. equivalent to roughly the amount of chemical energy used to create the ''implosion.'' Still other countries, such as Russia, might argue that hydronuclear tests are really ''safety tests,'' and for that purpose they need a limit of 10 tons,[13] in order to protect against the possibility that their calculations of the ''accidental'' yield are in error.

A very low limit on the nuclear energy released by such tests favors the weapon-states having either the greatest expertise, or the greatest available resources permitting gradual buildup of fissile material in the device through repeated testing to minimize the risk of ''overshooting'' and incurring a treaty violation. To be equitable and therefore viable in a negotiating context, such a hydronuclear testing regime might well require an accidental overshoot provision similar to the so-called ''whoops clause'' in the Threshold Test Ban Treaty that makes allowances for ''unintended breaches'' of the 150 kiloton treaty limit.

Moreover, because they result in vaporization and dispersion of toxic plutonium and small amounts of fission products, hydronuclear tests are most likely to be conducted underground at existing test sites. The activity surrounding preparations for such tests might not always be easy to distinguish from preparations to carry out the larger explosions banned by the treaty, thereby requiring provisions for cooperative verification of nuclear test activities at the site.

Other major unresolved issues in the ongoing CTBT negotiations include the duration of the treaty and the extent of permissible preparations to resume testing. With respect to the duration issue, it appears that a number of weapon states are exploring possible departures from the standard of ''indefinite duration'' accompanied by periodic reviews and a supreme national interest clause covering withdrawal from the treaty. For example, some weapon states are reportedly seeking special status for periodic safety and reliability tests that would be conducted within, or temporarily outside of, the Treaty regime. Others are reportedly exploring various contorted ''compromise'' formulations for a nominally ''indefinite'' treaty that would have low barriers to suspension or withdrawal after 10 years, or that would revert to a 10 year agreement with provisions for extension in the event that certain State Parties identify nuclear weapon safety or reliability concerns that do not rise to the level of a threat to their supreme national interests, but nonetheless merit rectification by a period of nuclear testing.

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[13] One senior Russian nuclear weapon scientist has recently expressed this view. See the "Report on the Sixth International Workshop on the CTB and Nuclear Warhead Elimination," sponsored jointly by the Natural Resources Defense Council, Federation of American Scientists, and the Moscow Physical-Technical Institute, Washington, D.C. December 15-17, 1993, p.11.

It should be noted that a failure to exclude the possibility of conducting hydronuclear tests, combined with various formulas resulting in an effective ten-year duration for the CTB, would likely prove fatal to achieving the goal primary goals of a CTB -- to halt further nuclear weapons modernization and test-dependent nuclear weapons proliferation. States Parties would have the latitude to use hydronuclear tests -- in addition to the wide range of non-nuclear test and simulation techniques already contemplated for exclusion under the agreement -- to develop a variety of "candidate" nuclear warhead designs, which could then be "proof-tested" at higher yields during the post ten-year "pause" or "time-out" period reportedly under discussion among the "P-5."

Since hydronuclear tests would most likely be conducted underground at the Nevada Test Site (NTS), the question of whether or not conduct them overlaps the broader issue which has arisen during the negotiations of regulating or banning "test preparations," possibly in conjunction with a requirement to close existing test sites and refrain from establishing new sites.

Both Russia and the United States have made known their intention to keep their respective nuclear test sites open. In the case of the United States, the proposed program for the year beginning October 1, 1995 includes the expenditure of $180 million to maintain the capability to conduct "a minimal test program within six months" and a "full test program" within 2-3 years. A number of governments, including Sweden, favor a broad ban on "preparations" to conduct nuclear tests. While a ban on "preparations" *per se* is likely to prove unworkable and unenforceable, Article I of the March 30 Australian draft text might usefully be modified to include a *prohibition on field preparations to contain, or recover data from, a nuclear explosion*. Thus amended, the Basic Obligation would now read:

> 1. Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, or any field preparations for containing or extracting data from, such explosions, and to prohibit and prevent such explosions and preparations at any place under its jurisdiction or control.

If the Basic Obligation were amended to bar both hydronuclear tests and test site preparations, it might read as follows:

> 1. Each State Party undertakes --
>
> (a) not to carry out:
> (i) any nuclear weapon test explosion or any other nuclear explosion;

(ii) *any release of nuclear fission [or fusion]*[14] *energy caused by the assembly or compression of fissile or [fusion material] by chemical high explosive means*;
(iii) *any field preparations for containing, or extracting data from, such explosions or releases;* and

(b) to prohibit and prevent such explosions, *releases, and preparations* at any place under its jurisdiction or control.

VIII. The Legal Status of Hydronuclear Tests: Are They Within the Domain of Nuclear Weapon Tests Regulated by the "Hatfield-Exon-Mitchell'' Amendment?

Whether or not a future CTBT bans hydronuclear tests, such tests are governed by the restrictions of Sec. 507 (the ''Hatfield-Exon-Mitchell Amendment'') of the Energy and Water Development Appropriation Act of 1992, P.L. 102-377, 106 Stat. 1343 (1992).

According to this statute:

''[Sec. 507 (f)] **No underground test of nuclear weapons** may be conducted by the United States after September 30, 1996, unless a foreign state conducts a nuclear test after this date, at which time the prohibition on United States nuclear testing is lifted.'' (emphasis added)

Sec. 507(b) provides that ''**no underground test of a nuclear weapon** may be conducted by the United States after September 30, 1992, and before July 1, 1993,'' and after the latter date Sec. 507(c) permits ''**an underground test of a nuclear weapon**'' only if, among other conditions, the President has submitted an annual report specifically identifying the permitted purpose of such test. (emphasis added)

The provisions of Sec. 507 clearly govern *all* underground tests of nuclear weapons, because the statute does not specify, or otherwise imply the existence of, a yield threshold below which underground tests would be exempted from the statute. There is little room for argument that, irrespective of whether the tests are for the purpose of weapons safety or weapon development, the items that have historically being subjected to hydronuclear tests are ***nuclear weapons*** or modified versions or prototypes of such weapons.

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[14] The inclusion of fusion energy releases in the prohibition would bar the kinds of demanding tests of spherical layered chemical implosion system symmetry using D-T gas mixtures (or solid mixtures of deuterides or deuteride-tritides of metals) that the Russian --and perhaps the U.S. -- nuclear weapons laboratories are known to have conducted. Such Russian "Gasdynamic ICF" (GICF) experiments have reportedly achieved a maximum 14 MeV neutron yield of 4×10^{13} in a system of 375 mm HE radius, that is, about two orders of magnitude below the ignition threshold. See Research Institute of Technical Physics, *The III-rd Zababakhin's Scientific Readings*, (abstract of reports), Dalnaya Dacha, Chelyabinsk Region, Ural, USSR, January 14-17, 1992, Chelyabinsk-70, 1991, p. 24.

However, because some may be tempted to argue that hydronuclear tests involve ''nuclear explosive devices'' rather than ''nuclear weapons,'' it is necessary to emphasize the fact that the Hatfield-Exon-Mitchell Amendment uses the terms ''nuclear weapon'' and ''nuclear explosive device '' interchangeably.

Sec. 507(a) of the statute makes funds available ''for conducting ***a test of a nuclear explosive device*** only if the conduct of that test is permitted in accordance with the provisions of this section.'' Sec. 507(e)(1)(A) likewise establishes the overall domain of tests covered by the statute by imposing a general standard that ''only those ***nuclear explosive devices*** in which modern safety features have been installed...may be tested.'' Thus tests of both nuclear ''nuclear explosive devices'' and ''weapons'' are covered by the statute.

Another line of argument has been to suggest that hydronuclear tests of nuclear weapons are not "nuclear weapons test explosions." Both legally and practically, if fissionable or fusion materials are removed from a nuclear weapon to lower its yield, the test of such a device is still recognized as a ***nuclear weapons test*** that must meet the limitations imposed by Limited Test Ban Treaty, the Threshold Test Ban Treaty, and the Peaceful Nuclear Explosions Treaty. By the same token, if additional fissile material is removed, or if the chemical high explosive is detonated asymmetrically, on what basis can one conclude that the event is no longer a ***nuclear weapon*** test, even if is given the more descriptive name, ''hydronuclear experiment?''

Since the Limited Test Ban Treaty was signed on 5 August 1963, DOE has acknowledged conducting 29 very low yield tests for one-point safety, and all were tested ***underground*** in compliance with the Limited Test Ban Treaty. As noted above, there are probably additional unacknowledged safety tests of extremely low yield that were nevertheless conducted underground in compliance with the terms of the LTBT prohibiting a ''nuclear weapon test explosion, or any other nuclear explosion,'' in any environment save underground. If a hydronuclear or safety test is a nuclear weapons test when conducted in the atmosphere, space, or underwater, why would it cease to be a nuclear weapons test when conducted underground?

There is no legal basis for concluding that a hydronuclear test conducted today should not be regarded as a ''nuclear weapons test'' falling within the scope of the Hatfield-Exon-Mitchell restriction. The DOE Office of General Counsel has (speciously) cited the existence of DOE internal orders -- characterizing a nuclear explosive as having a nuclear energy release equal to or exceeding the amount released by the detonation of four or more pounds of TNT[15] -- as evidence of a general public understanding that was shared by Congress when it debated and approved Sec. 507. However, these orders are nowhere referenced in the statute or even referred to in the legislative history.

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[15] DOE Order 5610.10, "Nuclear Explosive and Weapons Safety Program," defines a "nuclear explosive" as "any assembly containing fissionable and/or fusionable materials and main charge high explosive parts or propellants capable of producing a nuclear detonation," and DOE Order 5610.11 "Nuclear Explosive Safety," defines a "nuclear detonation" as "an energy release through a nuclear process, during the period of time on the order of one microsecond, in an amount equivalent to the energy release by the detonation of four or more pounds of TNT."

The only references to very low-yield safety testing during the debate were made by Senators Pell and Kennedy. Pell merely noted that "the U.S. criteria for safety is to virtually eliminate the possibility of an accident releasing a nuclear yield of more than the equivalent of four pounds of high explosive." His comment reveals nothing about the intended scope of Sec. 507.

Kennedy noted that concerns about accidental detonation "can be resolved with safety tests with an explosive power equivalent to a few pounds or less of TNT. Such tests need not be limited under a comprehensive test ban, because they are extremely small and would be almost impossible to verify." This statement has likewise been cited by the DOE as evidence of Congressional intent to exclude hydronuclear tests of four pounds or less from the scope of the Hatfield-Exon-Mitchell amendment's restrictions. We believe this interpretation is erroneous:

-- First, Kennedy's statement addressed the possible *scope of a future CTB*, not the scope of the legislative prohibition then under consideration;

-- Second, while Senator Kennedy was a supporter of the amendment and a longstanding supporter of a Comprehensive Test Ban, he did not participate in the Senate negotiations leading to the historic compromise amendment, nor did he engage in floor debate on the amendment other than to deliver a prepared statement.

-- Third, Kennedy's statement was simply an incontestable statement of fact, not intent-- "such [hydronuclear] tests [for safety] "need not be limited under a CTB." Then again, they could be limited. Kennedy did not address the question of whether he or anyone else believed such tests *should be* limited, as he was seeking to appeal, not to the supporters of a CTB in the Senate, but rather to its opponents and their ostensible concerns about weapon safety. To place these remarks in context, later in his statement Kennedy remarked,

> "We must avoid allowing safety testing to be the Trojan horse that defeats a comprehensive test ban. For forty years, the Department of Energy and the Pentagon have assured the American people that U.S. nuclear weapons are safe. But now that all other reasons for conducting nuclear tests have been swept away by the end of the cold war, they suddenly want us to believe that our most modern weapons are not safe."[16]

Thus a fair reading of Kennedy's statement would be that he personally did not feel that further testing for safety was warranted, but for those Senators that did, a CTB could be negotiated that accommodated very low-yield one-point safety tests. In other words, Kennedy's remarks would seem to have no bearing on the question of the intended scope of Sec. 507.

Section 507(d)(1)(B) required the President to submit a report to Congress containing a "plan for achieving a multilateral comprehensive ban on the testing of nuclear weapons on or before September 30, 1996." President Clinton has already gone on record that, in the view of the Executive Branch, this report requires "a plan...leading to a **total cessation of tests in 1996**."[17] Likewise, in its budget submission for FY 1994, the Department of Energy stated,

[16] Cong. Record, August 3, 1992, S11195.

[17] (emphasis added) *Cong. Record* (Senate) Feb. 16, 1993, p. S1513.

"**the law requires that all nuclear testing end on September 30, 1996.**"[18] Thus, Section 507(f) prohibits all U.S. underground testing, with no specified or implied exemption for hydronuclear tests, after September 30, 1996 and provides only a single exception: the detonation of a nuclear test by another country after that date.

The DOE Office of General Counsel (DOE/OGC) has seized on Sec. 507(f) to argue that Congress could not have intended to include hydronuclear tests within the scope of Sec. 507 because doing so would lead to an "absurd or futile result" that legal precedent admonishes us to avoid when construing the meaning of legislation. DOE/OGC argues that if Section 507 were read to preclude a test of a device capable of producing a yield of less than four pounds of TNT equivalent, it would then follow that a foreign state's conduct of such a test would result in the lifting of any and all prohibitions on U.S. testing after September 30, 1996. This line of reasoning leads to the presumptively "absurd" result that a foreign hydronuclear test with a nuclear yield equivalent to "0.001 pound of TNT" could have the effect of terminating all controls on U.S. testing under Section 507, and the conclusion that Congress could never have intended to construct such a trap-door under its own restrictions on full-scale U.S. testing.

Clearly, Congress clearly did not intend that inherently unpredictable events occurring after September 30, 1996 would have, indeed *could* have, any bearing on defining Executive Branch obligations under Sec.507 *before* that date. And yet that is precisely the structure of the DOE/OGC's argument. In reality, whether or not a foreign country tests after September 30, 1996 is irrelevant to a consideration of what kinds of tests may or may not be limited prior to that date, because the entire statute is devoted to establishing a program to restrict tests and encourage completion of CTB negotiations *before that date*.

The DOE/OGC goes on to argue that it would be more in keeping with Congressional intent if U.S. underground testing were permitted to resume only if a foreign test conducted a "significant" test -- significance in this instance being defined by DOE's internal orders (cited previously) that establish four pounds as the threshold for a 'nuclear detonation' controlled by the statute. This line of reasoning is momentarily appealing, but only until one recognizes that the same alleged "absurd or futile results" would logically ensue from a 5 pound, 100 pound, or 10 ton foreign detonation that *meets* DOE's criteria for a nuclear explosive test falling *within* the limitations imposed by the statute.

Moreover, the mechanism for making the determination that a foreign nation had indeed tested was not specified in the statute, so it is by no means clear that the normal workings of government would automatically lead to the self-nullifying result predicted by DOE/OGC. For example, the President, even if possessing knowledge of say, an Israeli hydronuclear test, might not provide such knowledge to the Congress or the public. What, then, would serve to trigger the legal termination of the restriction?

In reality, the likelihood of obtaining the feared "absurd or futile" outcome is not nearly as great as suggested by the DOE/OGC analysis. Under Section 507, Congress simultaneously

[18] Department of Energy FY 1994 Congressional Budget Request, Assistant Secretary for Defense Programs, Key Activity Summary, Weapons Testing, p. 77.

required the President to report annually on ''a plan for achieving a multilateral comprehensive ban on the testing of nuclear weapons on or before September 30, 1996.'' Clearly, Congress intended a CTB Treaty *to be in place by that date* that would provide a mutually agreed international framework for making the determination that a ''foreign state'' had indeed conducted a ''nuclear weapon test'' that merited the lifting the statutory prohibition on U.S. nuclear testing. Alternatively, Senate ratification of a CTB could well be accompanied by Congressional repeal of Sec. 507, in which case the scenario postulated by the DOE/OGC would not even arise.

In sum, the ''avoiding a futile result'' argument is a very thin reed on which to support a permissive construction of Congressional intent to exclude hydronuclear tests from the restrictions imposed by the Hatfield-Exon-Mitchell amendment.

X. Conclusion.

The principal nuclear weapon design concepts are generally known. The basic physical principles related to nuclear chain reaction, efficient implosion techniques by high explosive means, fission boosting, radiation coupling, and thermonuclear burn are widely available in the open literature. The basic physics parameters, such as nuclear cross sections, and equations of state, as well as computer codes for high explosive detonics, nuclear chain reactions, radiation transport, and thermonuclear burn, are freely available in the open literature.

Early, low-technology fission and thermonuclear warheads were designed without the benefit of high speed computers. Computer aided design and manufacture greatly facilitates optimizing weapon designs of all types, and predicting the yields. Most of the warheads in the U.S. stockpile were designed using computers roughly equivalent to today's personal computers. The desktop computers of the next decade are likely to approach the speed and storage capacity of today's mainframe supercomputers. A few unclassified fission weapon design codes have been written by researchers outside of the nuclear weapons laboratories, but these codes have not been calibrated against archival nuclear test data.

Full-scale nuclear testing is highly desirable for all but the lowest technology designs to provide confidence in the computer calculations, to better predict yields, and to optimize the designs with respect to yield-to-weight and yield-to volume. If full-scale nuclear testing is prohibited, hydronuclear tests can serve a useful role in the development of the full spectrum of unboosted fission weapons, including first generation nuclear weapons of the implosion type with yields in the 10 to 30 kiloton range, more sophisticated designs with yields up to about a megaton, and advanced micro-nuclear weapons with yields of 5 to 500 tons. Since hydronuclear tests do not generate sufficient yield to create the conditions for significant fusion of deuterium and tritium in the core, such tests do not provide a reliable means of extrapolating the performance of new boosted fission weapons, boosted thermonuclear primaries, or advanced thermonuclear secondaries.

In negotiating the CTBT the current strategy of the U.S. Government is not to define in the treaty what constitutes a nuclear test, and will interpret the CTBT to permit "treaty compliant experiments" up to some as yet undefined threshold to be agreed upon by the Permanent Five weapon states. A program of hydronuclear testing by any or all of the nuclear weapon states will likely encourage the undeclared weapon states, and perhaps other nations as well, to conduct similar tests at yields that may or may not conform to a mutually agreed threshold. All these states will then have acquired a license under the CTBT, to design *and test* a variety of new modern fission weapons, thereby undermining the purpose of the treaty.

Nuclear test sites of declared nuclear powers may be maintained, in part, to facilitate the conduct of hydronuclear tests. In the United States these tests would likely be conducted at Los Alamos National Laboratory or the Nevada Test Site. If hydronuclear tests are conducted at the respective nuclear test sites, which may be necessary for safety reasons, such tests will make verification of the CTBT increasingly difficult. Since the marginal value of hydronuclear tests to insure the safety and reliability of existing stockpiled weapons is very small, they should be explicitly banned under the CTBT. To do so we propose that the ''Basic Obligations'' of the parties under Article I of the Swedish or Australian draft CTB Treaty be amended to ban any nuclear weapon test explosion, or any nuclear explosion, **or the release of any nuclear fission [or fusion] energy caused by the assembly or compression of fissile [or fusion] material by chemical high explosive means.**

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