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NUCLEAR TESTING

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## THIRD GENERATION NUCLEAR WEAPONS AND THE NUCLEAR TEST BAN

**If nuclear weapons testing continues, new and dangerous innovations will be made and both superpowers will have to struggle to maintain even the insecure positions they have thus far achieved. This is the message of the detailed and knowledgeable article supplied by bomb designer Theodore B. Taylor.**

**But if true, what to do about it? Dr. Taylor and two equally well-informed referees of his paper, Richard Garwin and Carson Mark, disagree on the difficult choice of emphasis between efforts to secure a Comprehensive Test Ban Treaty directly, and an effort to negotiate a low threshold test ban limiting underground nuclear tests to 1 kiloton or 5 kilotons.**

**Each approach has problems. Most likely the low threshold should be seen as a plausible interim agreement en route to the comprehensive treaty. Then the threshold agreement might open new paths in verification that would satisfy the body politic that the comprehensive agreement was achievable.**

**A third reviewer of the article, Christopher E. Paine, warns, on the basis of past experience, against accepting uncritically estimates of what future testing might produce in the absence of agreement or under a low threshold. His analysis of the prospects for a test ban includes the possibility that expectations for new developments in testing might diminish, rather than excite, interest in a test ban.**

## NUCLEAR TESTING IS A PANDORA'S BOX

Theodore B. Taylor

Pandora had only one box. Ours are countless. Some have labels because we have opened them or peeked inside. As we label them, we try to stack them, like sorted goods in a warehouse. One stack is labeled "nuclear weapons." Next to the label is a note, left by a modern Prometheus: "Beware of $E=mc2$."

Some of these boxes are open, in spite of efforts of a few to try to slam them shut more than 40 years ago—first generation fission bombs; first generation hydrogen bombs; boosted fissions bombs; neutron bombs; tactical warheads; ballistic missile warheads.

The boxes yet unopened are enticing to some who have peeked inside: weapons that point and kill from space 1,000 miles from their target; weapons tuned to frequencies that will burn out computers, antennas, relays, powerlines; weapons that kill by blast and fire, but not gamma rays, neutrons, and radioactive fallout; small nuclear explosives that require no fissionable materials; and on and on.

The Soviet Union is telling the United States: "Let us join in first stopping, as we have, all nuclear tests, and then getting rid of all nuclear weapons as fast as we can."

They have said all tests, but after Reykajavik, they offered to accept partial measures.

The Reagan Administration's response has been a flat refusal to stop testing until Star Wars has "render(ed) nuclear weapons impotent and obsolete."

The new Congress is likely to press for some kind of test ban treaty. A widely held view in Congress, however, is that the United States should not make any test ban agreement that can be violated without high assurance that the violation will be detected and identified. This view is the impetus behind proposals for a low threshold treaty, the threshold perhaps being established by expected limits in sensitivity of in-country seismic arrays for identifying nuclear explosions.

Low threshold test bans are not without problems. Monitoring for violations of them requires not only identification of nuclear tests, but also measurement of their yields. At a threshold yield of, say, 1 kiloton, pressures to test just below that yield will be considerable. If, as can be expected, testing continues at a high rate, tensions over claimed violations can be expected.

The greatest risk in proposals for lower threshold test bans is that they will be rejected by the Reagan Administration and the Soviets, each for quite different reasons than the other, leaving us all at the arms control impasse where we are now. Although a 1 kiloton or greater threshold treaty will not kill Star Wars, or even nuclear versions of Star Wars, the Reagan Administration has given every indication of not wanting to impose further yield limitations on Star Wars-related tests. The Soviets presumably don't prefer a low-but-not-zero threshold test ban at least partly because they do want to stop Star Wars dead in its tracks. They may also, as they should, worry about the United States opening modern Pandora's boxes full of all kinds of very sophisticated new types of nuclear weapons.

Some advocates of a low threshold ban are reluctant to propose a comprehensive ban only because they worry about Soviet cheating that is not discovered. But I know of no evidence that this risk has been examined in the light of the full array of possibilities for verification. These include much more sensitive and discriminating seismic detection and identification systems (especially ones that make full

**Paine pg. 11; Mark pg. 12; Garwin pg. 13; Arms Control pg. 15**

use of much higher than traditional frequencies). Verification of compliance down to remotely unobservable yields, however, would depend on intelligence gathering operations, use of satellites dedicated mainly to searches for signs of unusual activity indicative of preparations for nuclear tests, and dissidents who become informers. International political repercussions can be expected to be a strong deterrence to cheating, and could be amplified.

Cheating at low yields, furthermore, will not pose new military threats unless they result in deployment of new weapons. Preparations for deployment of new types of weapons for new purposes resulting from very low yield testing will take years, and levels of actual deployment that can seriously effect the balance of military power will require many years after that. Unobserved action related to such deployment will become more and more difficult as the years pass.

Such possibilities for both verification and deterrence against cheating should be incorporated into a comprehensive bilateral test moratorium or treaty, or an international comprehensive test ban treaty.

I have no hesitation whatever in pressing strongly for a comprehensive test ban treaty between the United States and the Soviet Union as soon as possible and for taking the steps necessary to extend that treaty worldwide. The risks to the United States in particular, and to humanity in general, are far less than the risks inherent in opening anymore Pandora's boxes in the growing stockpile in the nuclear weapons corner of the warehouse.

If such efforts fail I would take what I could get, at some threshold well below 150 kilotons.

## Broad Functions of Nuclear Tests

Nuclear tests can be grouped into categories that relate to (1) development of new nuclear weapons; (2) understanding the effects of nuclear explosions; (3) verification of the reliability and safety of deployed nuclear weapons; and (4) development of peaceful uses of nuclear explosives. The objectives of any particular test, however, often include significant overlaps of these categories. Questions about the reliability of deployed nuclear weapons, for example, can relate to possible deterioration of weapons during peacetime storage, but also to their vulnerability to the effects of nuclear explosions (including side effects of "friendly" explosions) in wartime. Development of new types of weapons designed to enhance the release of specific forms of energy, such as X-rays or neutrons, for example, requires testing of the behavior of the nuclear explosive itself, as well as observing the effects of the enhanced energy on various types of potential targets. An example of the overlap of military and peaceful functions of nuclear tests is the use of a military weapon, perhaps of new design, for demonstrating the use of nuclear explosives for large scale excavation. A related example is laboratory and field tests of inertial confinement approaches to controlled fusion, wherein very small droplets of thermonuclear fuel are imploded by many laser, electron, or beam pulses to extremely high temperatures and densities, producing nuclear explosions with yields equivalent to a few tons or less

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of high explosive. Such tests are also part of the search of ways to make pure fusion weapons.

Such overlaps are discussed in more detail in the following summary of different types of functions of nuclear tests.

### Weapon Development Tests

*Pure Fission Weapons*: Calculations, laboratory experiments, and field testing of all the components of pure fission weapons except the fissionable cores (for which ordinary uranium can be used as a substitute) can allow development of weapons of this type without full scale nuclear testing. This option has become increasingly practical for countries developing their first nuclear weapons as the needed analysis tools and other relevant technologies have become more and more accessible worldwide. It has also been credible for at least a dozen years that designs used for a country's first nuclear weapons can be more advanced than the initial designs used by the present five declared nuclear weapons states, yet not require nuclear testing to give fairly high confidence that their yields will be orders of magnitude greater than any chemical explosive weapons.

This confidence can be increased by "zero yield" nuclear testing. This approach involves conducting tests of implosion systems with smaller quantities of the fissionable core materials than needed for the full design yield. This can be done by producing a fission yield high enough to be observable with radiation detectors placed close to the weapon, but still equivalent to less than 1 *gram* of high explosive. Such extremely low energy releases correspond to about 20 generations of a fission chain reaction, compared with something like 45 generations to build up to a yield equivalent to a few tons or more of high explosive.

Such tests require much sophistication, especially if it is important that errors in design not cause the yield to be dramatically greater than intended. One way to reduce this risk is to plan several tests, starting with so little fissionable material that a high yield, by mistake, is extremely unlikely, and then increasing the material as indicated by test results and corresponding calculations.

Extremely low yield nuclear tests typically are more stringent tests of the overall behavior of the weapons assembly system than tests of the nominal weapon itself, since imperfections in the system have more effects on tests at very low yield than at high yield. It is for this reason that such tests can be useful to countries with considerable experience with nuclear weapons, including a history of testing. But they can be even more useful to countries starting nuclear weapon development, if they want to test without being noticed.

Limits to the yields of fission weapons are more likely to be set by accessibilty to the needed plutonium or highly enriched uranium than by any inherent design limits, since it is possible to make pure fission weapons with yields in the range of hundreds of kilotons. Complete fission of 1 kilogram of plutonium or uranium yields 17 kilotons. To countries that do not have access to large quantities of these materials it may be much more important to have a number of weapons with yields of the order of a few kilotons than a smaller number with yields in the range of tens of kilotons or higher.

The yield-to-weight ratio of the implosion weapon dropped on Nagasaki was about 0.004 kilotons per kilogram. Since that time pure fission weapons have spanned yield-to-weight-ratios ranging from a high in the vicinity of 0.1 to a low of about 0.0005 kilotons per kilogram. This indicates that, for high yield-to-weight ratio pure fission weapons that have been developed, something like 100—200 kilograms of total weight are required for every kilogram of fissionable material consumed. This considerable added weight is accounted for by limits on the efficiency of fission of the fissionable material core, and the weights of neutron reflectors around the core, high explosive in the implosion system, fusing and firing equipment, and some kind of outer case.

The range of yields of tested pure fission weapons extends from close to zero up to about 500 kilotons. Weapon diameters span a factor greater than 6, from less than ten inches to about 60 inches.

How close such overall measures of performance have come to fundamental limits set by basic material properties, including critical masses of fissionable materials, cannot be established from information that is not classified.

*Boosted Fission Weapons*: The yields of fission weapons with moderate to low efficiencies can be substantially increased by incorporating small quantities of tritium and deuterium that react and release high energy neutrons into the fissioning material while the chain reaction is still rapidly multiplying the number of neutrons present. Although details of this process are classified, it is well known that complete fusion of, say, 3 grams of tritium will yield about the same number of neutrons as produced by a 4 kiloton pure fission explosion. The energy of a neutron released

### RECENT DEVELOPMENTS

**• The Soviet Union announced a unilateral moratorium on all nuclear tests, starting August 1985, and has extended this until January 1, 1987. No violations of this self-imposed moratorium have been reported. The U.S. has performed at least 18 nuclear tests since the start of the Soviet moratorium.**

**• The U.S. has tested at least one type of directed energy nuclear weapon (an X-ray laser) for possible use in Star Wars. Other possibilities for "third generation" nuclear weapons (fission and thermonuclear weapons being the first two) have been discussed recently, but not in any detail.**

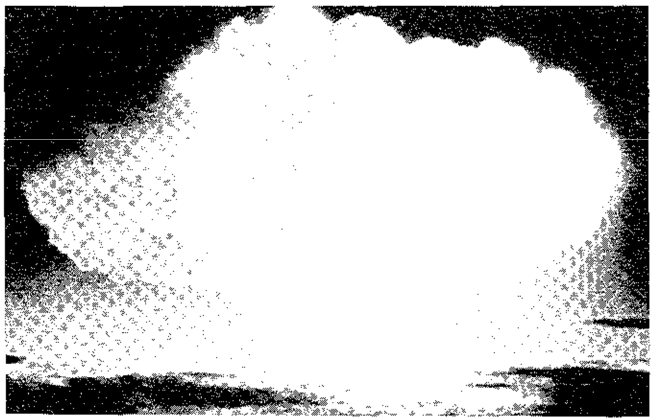
**• Last August the U.S. House of Representatives passed, by a 79 vote margin, an amendment to the defense authorization bill denying funds for all nuclear tests with yields above 1 kiloton during calendar year 1987. This amendment was conditioned upon equivalent Soviet restraint and willingness to accept adequate verification measures. It was removed from the authorization bill just prior to the Iceland Summit meeting in October.**

from this type of fusion reaction are considerably greater than the energies of neutrons released by fission. It is thus clear that fusion of a few grams of tritium in the immediate vicinity of a fission chain reaction that would yield a few kilotons without boosting is likely to increase the fission yield substantially. The increase in yield is almost entirely accounted for by the increase in fission energy, not the energy directly released by fusion (equivalent to roughly 120 tons of high explosive per gram of tritium consumed).

Testing of boosted weapons requires high enough temperatures in the fissioning explosive to ignite the thermonuclear fuel. These temperatures depend on the unboosted efficiency of the weapon—the lower the efficiency, the more difficult it is to cause ignition. It is therefore clear that there is some minimum threshold yield below which tests of boosting are not possible. This threshold yield decreases with increasing effectiveness of a weapon implosion system in compressing the fissionable material, since higher compressions allow smaller yields to be achieved at some small efficiency. Deviations from idealized, calculated performance, however, along with the considerable complexity of the boosting process itself—involving important feedbacks between fission and fusion as the explosion proceeds—tend to make it necessary to test boosted weapons at full yield if they are to be put into weapons stockpiles. It is difficult to imagine militarily attractive boosted weapons with yields less than 1 kiloton or so. The reason for this is that the unboosted yield would be significantly less than 1 kiloton, yet achieved with sufficient efficiency to ignite the thermonuclear fuel. A fission yield of, say, 0.25 kilotons corresponds to the fission of 15 grams of plutonium. Achieving this low yield at some reasonable efficiency, enough to ignite the thermonuclear fuel, would therefore correspond to using an amount of plutonium dramatically smaller than its normal density critical mass, which is in the vicinity of 5 kilograms.

Since the added weight required for boosting is very small, boosted weapons generally have yield-to-weight ratios substantially greater than pure fission weapons with rather low efficiencies. Yields of weapons with fixed dimensions can also be increased substantially by boosting.

*Thermonuclear Weapons That Require Fission Triggers*: These are usually defined as explosives in which the energy of the thermonuclear reactions is a significant fraction of the total yield, as opposed to boosted weapons, where it is not. This distinction is somewhat arbitrary, however, since a nuclear explosive with fusion-to-fission yields ranging from close to zero (very "dirty," in terms of radioactive products per kiloton) to much less than 1 ('clean H-bombs') have been tested. The definition has also generally applied to explosives requiring a fission "trigger" to ignite the thermonuclear fuel. The "cleanest" nuclear explosive ever tested was probably the nearly 60 megaton weapon exploded by the Soviet Union at high altitude in 1961. The fusion-to-fission ratio in this explosion could well have been much more than 10%. This was accomplished by designing the explosive such as to avoid exposure of fissionable material to a majority of the neutrons released by the thermonuclear fuel.


*The mushroom cloud from the first thermonuclear explosion, over 1,000 times bigger than the Nagasaki bomb.*

So-called "neutron bombs," for which the design criterion is to achieve a high output of energetic neutrons per kiloton of yield, represent a class of thermonuclear weapons with still lower yield. The neutron absorption properties of air are such that neutron weapons with yields greater than a few kilotons cannot be used effectively in the atmosphere without having blast effects dominate radiation effects.

What is the lowest possible total yield from a thermonuclear explosive in which fusion is triggered by fission? The answer depends on how effectively energy from very low yield fission triggers can be transferred to thermonuclear fuel that is not in the vicinity of fissionable material. How this might be done cannot be discussed publicly. Basic considerations of energy densities in low yield nuclear explosives, easily more than 1,000 times those associated with chemical explosives, do not, however, rule out the possibility that such a lower limit might be significantly lower than 1 kiloton.

*Pure Fusion Explosives*: Vigorous efforts to develop pure fusion weapons that do not require any fission trigger explosion have been underway for at least 30 years. These efforts have so far apparently been unsuccessful, although it is possible that success in one or more countries has been kept secret.

A related technology, the "inertial confinement" approach to controlled fusion for the production of electric power, has also been seriously investigated in about a dozen countries for more than a decade. These techniques use highly focused laser or electron or ion beam pulses, converging on small pellets or droplets of thermonuclear fuel, to implode them to extremely high densities and temperatures. The objective is to create very small thermonuclear explosions, with yields equivalent to a few tons or less of high explosive. The explosions are contained in such ways that their energy can be converted with high efficiency to electric power. The goal is to extract 10 to 100 times as much useful energy from the explosions as is expended in the lasers or electron beams used for ignition of the fuel. An electric power station based on this energy source would in some ways be analogous to a huge internal combustion engine, detonating at least a few thousand thermonuclear explosions per day if each explosion were equivalent to a dozen or so tons of high explosive.

In the United States work on fusion by inertial confinement has been largely financed under the Department of Energy's military programs, since much of the information gathered from it is directly applicable to attempts to make pure fusion weapons. No-one is suggesting that an inertial confinement system, along with rooms full of lasers or electron guns and the associated electrical equipment, would be suitable for a military weapon. But the basic mechanisms of the fuel ignition and explosion would be directly relevant to pure fusion weapons that used much lighter and compact equipment energized by some concentrated source of chemical energy to implode the thermonuclear fuel. The work on such energy sources and energy conversion methods remains classified, but results of many of the detailed calculations and experiments related to the behavior of imploded fuel have been widely published.

Tests of many features of these techniques can also be made with plutonium pellets weighing a few grams. The highly focused implosion technique is designed to compress the fuel or plutonium to more than 100 times their normal densities. Since the critical mass of material that can support a chain reaction (or uranium-235) is inversely proportional to the square of its density, 2 grams of plutonium compressed 100-fold would represent about 4 critical masses. The result would be a rather efficient explosion, with a yield equivalent to more than 5 tons of high explosive. It follows that successful development of compact implosion systems capable of this kind of performance could make possible not only pure fusion weapons, but also a full range of fission or fission-fusion weapons requiring extremely small quantities (a few grams or less) of key nuclear materials such as tritium or plutonium. Such devices could be used to trigger subsequent stages of much higher yield, without requiring any more key nuclear materials.

### Weapons With Enhanced and Suppressed Effects

All the above types of nuclear weapons release substantial quantities of different types of energy or energy carriers. These include gamma rays; X-rays; neutrons; radioactive isotopes; electrons; alpha-particles; vaporized (and initially ionized) materials associated with all the components of the weapon, and pulses of electromagnetic radiation generated from electron currents in the expanding materials. The relative quantities of these depend on the design of the weapon.

Many of these forms of energy directly emitted from an exploding weapon can interact with the explosion's environment (the atmosphere, ground, ocean, or the earth's magnetic field, for example) in ways that convert the energy from the weapon into other types of energy that can cause important intended or unintended effects. Such secondary energy carriers include air, ground, and water shock waves; ground dust or large, high speed objects ejected from craters or destroyed buildings; water waves and long wavelength water swells (tsunamis); visible and ultraviolet light; heat; smoke and combustion gases released by fires ignited by the heat; radioactive isotopes resulting from bombardment by neutrons; and a variety of types of pulses of electromagnetic waves with wavelengths ranging from the far infra-red, through microwave, radar, TV and radio, to many kilometers.

The relative quantities of these secondary forms of energy and materials depend not only on the environment of the explosion, but also on the design of the weapon itself. The environments of the explosions can be deep space; near space within the earth's magnetic field but outside the atmosphere; the atmosphere at high, intermediate and low altitudes; the surface of the ground, fresh water bodies or the ocean; below ground or underwater; and in the midst of large man-made structures such as buildings or dams.

It is also possible to add components to the exterior of a nuclear explosive to convert some of its energy into forms that are not normally released from a nuclear explosion. Examples include means for production of very high velocity solid or liquid fragments; laser beams at X-ray or other wavelengths; and much longer wavelength electromagnetic radiation.

The "clean" thermonuclear weapons and neutron bombs mentioned above are two examples of a huge number of possibilities for designing nuclear weapons, and selecting the environment for their use, in ways that will strongly enhance or suppress any or several of these many different primary or secondary forms of energy, along with their ultimate effects.

Development of such possibilities requires thorough understanding of the relevant effects of nuclear explosions. These effects relate not only to ultimate effects on targets, but also to energy conversions and transfers in the environment affected by the explosions. The sections that follow therefore summarize some of the most important energy conversion phenomena caused by nuclear explosions in different environments.

Nuclear weapons intended for use in space or at high altitude in the atmosphere offer many more opportunities for enhancement of selected effects at large distances than nuclear weapons exploded at low altitude or beneath the

### BETHE ON X-RAY LASERS

**SENATOR KENNEDY (to Dr. Hans Bethe):**

**Are you familiar with the Administration's development and testing of new concepts for nuclear driven directed energy weapons called "nuclear-pumped X-ray Lasers?" In your view, how many years are we away from being able to "weaponize" the nuclear-pumped X-ray laser concept?**

**DR. BETHE:**

**I am familiar with the development and testing of nuclear-pumped X-ray lasers. It is difficult to answer your question because this development is in its infancy. It is not at all clear whether any amount of testing will lead to a militarily useful X-ray laser. If there is a success at the end of the road, I estimate that between 10 and 20 years of testing will be involved. I would estimate the necessary number of tests, for research as well as development, to be 30 or 50. But Dr. Selden of Los Alamos, who has more experience in testing, estimates 100-200.**

surface. The reason is that in free space there is nothing, except the earth's magnetic field, to stop or deflect radiation or material; once they are released from the explosion, they keep on going until they hit the upper atmosphere or a target.

All nuclear explosion effects summarized above, can be selectively enhanced or suppressed, by orders of magnitude in some cases, by changes in weapon design. The partitions of energy between shock waves, heat, visible light, prompt and delayed radiation, and electromagnetic pulses of long wavelength can be changed significantly for weapons intended for surface, low altitude, or intermediate altitude detonations. More and more control of this energy partition, by changes in weapon design, becomes possible for higher altitude explosions, reaching a maximum set of options for weapons designed for use in space.

### Directed Energy Weapons

The energy outputs and ultimate effects of nuclear explosions can not only be selectively enhanced or suppressed overall, but also in particular directions. This is true of all the effects discussed above.

Details about how specific directional effects can be enhanced or suppressed are classified now or are likely to be when new ones are identified.

In quite general terms, however, it is clear that substantially more energy can be released within some angle than it would be if released uniformly in all directions. How effectively this can be done depends on how much a particular form of energy can be enhanced and channeled in a particular direction. Electromagnetic energy with wavelengths typical of gamma rays, x-rays, visible light, and microwaves can be focused by the equivalent of lasers. Longer wavelengths can be emitted directionally by the use of the equivalent of antennas. Limits to the angles within which significant fractions of the energy of an explosion depend on the energy conversion systems used and the dimensions of the means for focusing.

### Weapon Effects Tests

In broad terms, tests of the effects of nuclear explosions have concerned (1) the vulnerability of military systems to enemy and "friendly" nuclear explosions, and ways to decrease such vulnerability; (2) intended effects of a country's weapons on military and civilian targets; and (3) unintended side effects of nuclear explosions.

Such tests are often supplemented, or sometimes made unnecessary, by using laboratory and field simulation techniques that do not require nuclear explosions. Examples are electrically powered X-ray pulse generators; pulsed particle accelerators or nuclear reactors to produce bursts of neutrons or gamma rays; large facilities for testing EMP effects on large components; and high explosive detonations with yields as high as a few hundred tons, to observe effects of air shocks on military installations and equipment.

For simulation tests to be appropriate, however, it is necessary to know what to simulate. Uncertainties in this regard can sometimes be critical, since, as indicated in the preceding discussions of effects of nuclear explosions, they can be extremely complicated and difficult to predict, and may even have escaped notice. Another limit to the value of simulation tests is sometimes set by the extremely high intensities of incident energy to be simulated, especially those related to effects of protected equipment, such as warheads, close to a nuclear detonation.

Some, but by no means all important effects of nuclear explosions, especially at very high energy densities, can be simulated in underground nuclear tests. Such tests tend to be very expensive and complex, typically requiring several meter diameter evacuated pipes in tunnels extending several hundred meters or more from the explosion. Recovery of damaged materials or complex components exposed to X-rays or nuclear radiation travelling down these pipes generally require massive, fast closing barriers to later flows of other forms of energy. Furthermore, underground nuclear tests are also subject to the limitation of needing to know, in advance, much of what to expect, to assure adequate instrumentation and target sample recovery techniques have been put in place.

Except for effects of nuclear weapons intended for placement deep underground, none of the effects of interactions of nuclear weapon explosions with their environment, and their subsequent effects on military or civilian facilities or equipment, can be simulated in underground tests. Among the many examples are all EMP effects (many of which have been predicted but never measured); effects on radio and radar transmissions of changes in the ionosphere's chemical states and other properties; cratering phenomena; and underwater explosions.

It might be argued that the extensive above ground nuclear testing by the United States and the Soviet Union before 1962 has already provided the information needed for adequate assessment of the important effects of nuclear weapons. It is fair to say, however, that these tests generally raised more questions than they answered, and the present knowledge of the effects of nuclear explosions, especially in the upper atmosphere and in space, is rudimentary.

### Nuclear Weapon Reliability and Safety Tests

Tests in this category need to be considered in three contexts—peacetime, conventional wartime, and nuclear wartime.

### X-RAY LASER FAR OFF?

**More serious, however, is *The New York Times* reference to testing as needed for developing radically new nuclear weapons for the Star Wars program.**

**After five presumed tests in Nevada in six years, the nuclear-pumped X-ray laser program to develop this proposed directed-energy space weapon is still in its infancy. Weapon design experts at Los Alamos estimate that developing it might require 100 to 200 more nuclear tests (news story, April 21) and could easily require 10 to 20 more years. And if the device is ever perfected as a space weapon, its primary use will be in an offensive mode for attacking Soviet satellites.**

***—Letter to New York Times, Hugh Dewitt, Research Physicist, Livermore Laboratory. September 30, 1986.***

## DIRECTED ENERGY WEAPONS ARE "THIRD GENERATION"

**At a fixed distance from an explosion, it is easy to calculate the increase in the energy (or power) delivered per square meter if all the energy from an explosion is focused within a specified angle, compared with what it would be if that form of energy were released uniformly in all directions. If some fraction of the energy is contained within that angle, then the actual energy per square meter is proportionately higher.**

**This is why directed energy nuclear weapons qualify as "third generation" weapons. Even if small fractions of the total energy released by an explosion are directionally emitted, the result can be several orders of magnitude greater effect in that direction than for weapons that release their energy more or less uniformly in all directions. If 2% of the energy of an explosion is electromagnetic energy focused through an angle of 1 degree, for example, the total flux of energy in that direction is 1,000 times what it would be from a spherical explosion of the same yield.**

**Possible directional effects of other forms of energy, such as the kinetic energy in vaporized weapon materials, hypervelocity pellets or droplets, radioactive isotopes, neutrons, and blast waves are subject to constraints that are much more complex than those applicable to electromagnetic radiation, and cannot be discussed quantitatively here.**

**Use of directed energy nuclear weapons can produce significant side effects that are quite different from those caused by roughly spherically exploding weapons. An X-ray or gamma ray beam aimed downward into the upper atmosphere, for example, will generate an electron current along its path. This current might generate an electromagnetic pulse that is much different in character from those discussed above, and could cause transients or outright damage in equipment at long distances from the explosion. Such side effects would need to be understood in assessments of the military desirability of directed energy nuclear weapons.**

**Development of directed energy nuclear weapons provides two options. One is to reduce sharply the yield needed to produce a particular effect at some distance. The other is to increase the effect at some distance, without increasing the yield. In many cases the best option would be a combination of the two. As long as pure fusion weapons are not possible, directional enhancement of some effects, from some types of weapons, will not be possible below some yield threshold. As noted above, for example, high fusion yield thermonuclear weapons are likely to have threshold yields in the vicinity of 1 kiloton. But appropriate design changes might produce a desired effect at the same distance as from a conventional thermonuclear weapon with a yield in the megaton range. Pure fission weapons, on the other hand, can be designed with yields arbitrarily close to zero. At very low yields some forms of energy, such as released X-rays, may be produced with much too low efficiencies to make directional enhancement feasible. But use of very low yield explosions to propel weapon debris or hypervelocity pellets or droplets, or directional blast waves in air or water, may have exploitable military applications.**

It is the avowed policy of all present announced nuclear weapon states that the function of their nuclear weapons is to deter military attacks by other countries. In the case of the United States, at least, this deterrent function applies both to nuclear and to non-nuclear attacks, including Soviet attacks of NATO forces. In this peacetime condition, all the nuclear weapon states want to be sure that considerations of the reliability of their nuclear weapons systems, including the nuclear warheads themselves, will not detract from their deterrent value. They also want the overall risks of any of their nuclear weapons accidentally exploding with a significant nuclear yield or releasing radioactive weapon materials, such as plutonium or tritium, to be no greater than, and perhaps much less than the risks associated with maintaining other military equipment in peacetime.

Nuclear weapons in stockpile can, in time, deteriorate sufficiently for their performance to be questionable. Such deterioration can be caused by internal chemical reactions (especially with water or humid air), radioactive decay of some component materials, mechanical damage due to handling, exposure to extreme changes in temperature, and other changes that can occur in any complex equipment in storage for a long time. The principal way to assure reliability of the weapons is by periodic inspection of a few weapons, including dismantlement if deemed necessary, and replacement of faulty components in all the weapons of that type if a significant fraction of the sampled weapons indicate such a need. Although nuclear tests of weapons taken out of stockpile are occasionally performed, this is not an effective way to assure reliability. Failure of a weapon to produce its normal yield will not reveal the cause, and observation of a full yield is no guarantee that most of the other weapons have not deteriorated seriously.

Use of new techniques for refabricating parts of weapons may introduce changes that will affect their performance. Refabricated weapons are sometimes tested for that reason. If such a weapon should fail a nuclear test, however, it is difficult to know what caused the failure, and correct it. Once a new type of warhead has gone into production, and the production item test fired, the best way to assure reliability is to avoid significant changes in fabrication techniques that might effect performance, and maintain an appropriate quality assurance program based on periodic sampling. This is not to say that occasional testing for reliability is never useful, but it is far less effective than careful inspection and quality control.

Requirements that accidental detonations of high explosive in nuclear weapons cannot result in a significant nuclear yield have led to tests of assembled weapons that have so much fissionable material that this is a possibility. Some of these "one point" (i.e. one detonator fired) tests have produced a significant nuclear explosion. Whether or not such tests are justified for new weapons depends in detail on their design.

Considerations of safety and reliability of nuclear weapons in a nuclear war are dramatically different from those relevant to peacetime or a non-nuclear war. Maintaining reliability of strategic or tactical nuclear weapons would require prior hardening against the effects of nuclear explosions on all key elements of nuclear weapon systems. Nuclear warhead safety would be of lesser concern under such conditions.

Many nuclear tests have been primarily for the purpose of testing the effectiveness of such hardening techniques. But, there are no prospects for realistic tests of the overall effects of numerous wartime nuclear explosions on military *systems*.

### Nuclear Tests for Peaceful Purposes

High yield thermonuclear explosives are the lowest cost source of energy ever developed. Mass produced thermonuclear explosives could cost less than $1 per ton of coal in equivalent energy. They also offer opportunities for achieving much higher energy densities, at low cost, than any other energy conversion system. It is for these reasons that considerable effort, including dozens of nuclear tests, has gone into searches for ways to use nuclear explosives for practical non-military and scientific purposes.

Several of the tests partially in this category have been underground tests of weapons also used as neutron sources for performing basic physics experiments not related to nuclear weaponry. Many, and perhaps all of the tests related to excavation and stimulation of release of natural gas have used either stockpile nuclear weapons or modified nuclear weapons.

If development of peaceful uses of nuclear explosives gets to a stage of routine use, however, new design features to make them more appropriate would often be desirable in the explosives. An example is development of "ultra-clean" thermonuclear explosives, perhaps having the added feature that any radioactive products are channeled into a relatively small volume cavity that is then shut off from the regions where the bulk of the excavation is to be done.

In any case, nuclear explosions said to be for peaceful purposes have been significant parts of nuclear test programs, and can reasonably be expected to continue as long as military testing does. The levels of such testing, however, are lower than they would be if uncontained nuclear explosions were allowed.

### Arms Control Implications of Alternative Restrictions on Nuclear Testing

In the light of the preceding discussion of functions of nuclear tests, let us now examine the impact on the nuclear arms race of several alternative future restrictions on nuclear testing, ranging from the present situation to a worldwide Comprehensive Test Ban Treaty.

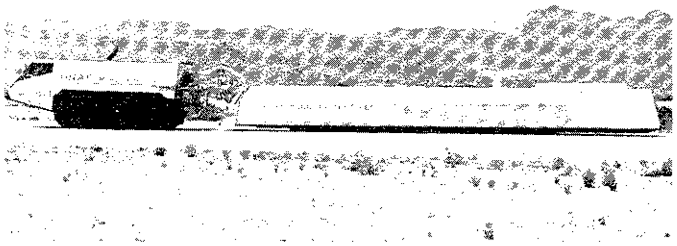
### Continuation of the Soviet Unilateral Moratorium

The Soviet Union's present unilateral moratorium on nuclear tests cannot be expected to continue much longer if the United States does not follow suit. It is possible, however, that the Soviet Union will extend its moratorium again, beyond the end of this year, until it is clear whether or not Congress will apply sufficient pressure on the Reagan Administration to reverse, at least for a limited time, the present U.S. position that it must continue testing as long as the U.S. relies on nuclear weapons for its security. Application of such pressure is complicated by the fact that stopping nuclear tests by the U.S. would stop further testing of possible nuclear warheads for SDI. The refusal by the Reagan administration to give up intensive work on SDI, and the substantial congressional support for SDI R&D, at least, can be expected to make it more difficult to change the U.S. position on testing. If this change does not take place soon, it is unlikely that the Soviet Union will extend its moratorium until the 1988 U.S. elections. Thus the present situation may soon revert back to a continuation of the era of the Threshold Test Ban Treaty.

### Continuation of the Present TTBT Without Further Restrictions

A particular arms control impact of the present TTBT is the extension of considerable uncertainties about the vulnerability of nuclear weapons and other military systems to the effects of nuclear explosions. These uncertainties are much greater than the performance of nuclear warheads now in stockpile or to be deployed in the future if they were detonated, as in an underground test, in peacetime. The reliability of strategic nuclear deterrent systems in a nuclear war will therefore continue to be open to serious question.

As indicated above, the full range of vulnerability of launch complexes, command and control systems, and other key components of nuclear weapon systems to the huge variety of effects of enemy or "friendly" nuclear explosions near the surface, at higher altitudes in the atmosphere, and in space cannot be adequately determined by underground nuclear tests.



*Without above ground testing, the vulnerability of the Midgetman Hard Mobile Launcher to the combined effects of nuclear explosions remains uncertain.*

Such uncertainties will persist for all countries, however. It is therefore extremely unlikely that any nation will feel confident enough about the reliability of its own and the unreliability of the enemy's nuclear weapon systems, in a state of nuclear war, to be willing to launch a first strike against a major nuclear power.

These kinds of uncertainties are considerably amplified for extensive or limited versions of SDI, whether or not its weapons include nuclear warheads. In particular, SDI would be especially vulnerable to the direct and indirect effects of nuclear explosions in the upper atmosphere or in space. Such explosions could be precursors to a strategic nuclear attack. The nuclear warheads for this purpose might be launched by exceptionally high thrust missiles designed specifically for this purpose. The explosions might also be caused by use of salvage fusing of the strategic warheads, causing them to explode just before being damaged by SDI weapons. The explosions could also be detonations of SDI nuclear warheads.

A condition for deployment of an SDI system is therefore likely to be prior nuclear tests in the atmosphere and in space, in violation of the TTBT, to assure the system's survivabilty in the face of nuclear countermeasures. This assurance cannot be provided by using the results of simulation tests, including underground nuclear effects tests. One of the many reasons for this is that the natures of the effects to be simulated are largely unknown.

Further development and testing of many new types of nuclear warheads, including many types of directed energy weapons, can be expected to proceed under the restrictions set by the TTBT. Some of these could be eventually deployed with about the same confidence in their reliability in wartime as now applies to currently deployed nuclear weapon systems. Others, especially weapons designed to couple with their explosion environment in new ways, could not. In the latter case, pressures for resumption of tests above ground or under water could be expected to mount.

### A Low Threshold Test Ban Treaty (LTTBT)

Pressures, in Congress and elsewhere, for a Comprehensive Test Ban Treaty (CTBT) have clashed with widespread insistence that adherence to any new treaty be verifiable. Experts differ concerning lower limits to test yields that could be reliably detected remotely by networks of seismic stations. Attempts are therefore being made to reach a compromise, in which the present TTBT threshold of 150 kilotons is lowered substantially, but not below the lower limit of reasonably assured detectability by extensive seismic detection networks in both countries.

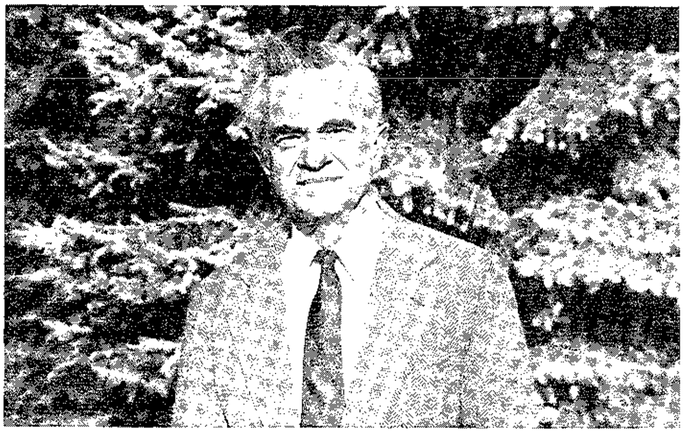
The choice of such limits is complicated by possibilities for reducing the seismic signals from underground tests, including detonating the explosive inside a large cavity. Given these uncertainties, several different thresholds for a reduced threshold treaty (LTTBT) have been proposed, ranging from 1 kiloton to about 15 kilotons. Proposals have also been made to allow a small number of tests per year at higher yields, up to the present 150 kiloton threshold.

At a 1 kiloton threshold, without permitting any higher yield tests, nuclear weapon development and effects tests would be sharply curtailed, but not eliminated. Adherence to such a treaty would prevent the following:

- Full yield tests of replacements for all present strategic nuclear warheads, and nearly all present tactical warheads of the present nuclear weapon states, at yields similar to what they are now.
- Full yield tests of fission triggers for the present types of strategic thermonuclear weapons of the nuclear weapon states, along with partial yield tests of any of these weapons.
- Development, by countries other than the present five nuclear weapon states, of strategic thermonuclear weapons similar in design to those developed by the nuclear weapon states.
- Tests of boosted fission weapons, unless the country were willing to accept a considerable risk that the yield might exceed one kiloton

A TTBT with a 1 kiloton threshold would not, however, prevent:

- Development of any of a wide variety of new types of low yield weapons, especially directed energy weapons for SDI and countermeasures for such weapons. Energy densities and corresponding pressures and material velocities orders of magnitude greater than in high explosives can be produced in nuclear explosives weighing less than 100 kilograms, with yields below 1 kiloton. It is to be expected, therefore, that the variety of options for producing special effects, such as penetrating jets of material; hypervelocity pellets; directional shock waves in air or water; and flashes of short, medium, and long wavelength radiation would be considerably greater than the already very diverse types of military applications of high explosives.
- Tests of some of the effects of nuclear explosions, using very low yield nuclear explosives designed specifically for this purpose. Although such tests would not answer many of the questions related to survivability of nuclear weapon-systems in a nuclear war, and would be more restricted than under the TTBT, they would help in the assessment of weapons designed to produce special effects. A completely contained, reusable facility for performing such tests, at yields up to about 0.3 kilotons, has been seriously studied



*Theodore B. Taylor*

at Lawrence Livermore National Laboratory. Such a facility would be seismically quiet.

- Proliferation of pure fission weapons with reliably predictable yields up to the vicinity of 100 kilotons. Development of the weapons could make extensive use of non-nuclear testing of implosion systems, "zero yield" tests, and reduced yield tests of systems that could be assured to produce much higher yields with larger cores of fissionable material.
- Development of pure fusion or very low yield fusion-fission explosives if such explosives turn out to be possible. A 1 kiloton threshold would have no effect at all on present and forseeable possible future efforts to develop such low yield explosives.

Increasing the threshold to 5 kilotons would significantly increase the assurance of seismic detection of violations. It would, however, make it much easier to test boosted weapons and some types of fission triggers for thermonuclear weapons, and would allow full yield testing of a greater variety of new types of SDI and tactical warheads than allowed with a 1 kiloton threshold.

At a 15 kiloton threshold, seismic decoupling would be extremely difficult. But it would allow further development of all types of nuclear weapons by the nuclear weapon states, except for major changes in high yield thermonuclear weapons. Other countries could develop most types of nuclear weapons, notably excluding high yield themonuclear weapons, however.

Resolution of issues related to peaceful uses of nuclear explosions would require major decisions and negotiations before a LTTBT took effect, since such a low threshold would be below yields required for most peaceful applications of nuclear explosions that have been seriously pursued or proposed.

### Comprehensive Test Ban Treaty (CTBT)

A CTBT is often defined as one that prohibits all tests of nuclear explosives except, possibly, separately negotiated tests related to peaceful uses. But such a definition leaves open a number of issues centered on the exact meaning of the phrase "nuclear explosives." Are very low yield tests of inertial confinement approaches to controlled fusion, with or without tests using gram quantities of plutonium, included? "Zero yield" tests of implosion systems? Tests to determine the extent of dispersal of plutonium by accidental detonation of nuclear explosives that do not produce a nuclear yield? Nuclear reactor tests that produce significant chemical or steam explosions? Such questions need to be answered to determine the impacts of a CTBT on nuclear weapon development, and on the specific arrangements for verification.

Nuclear explosion is sometimes defined as one for which the nuclear yield is substantially greater (e.g. 10 or 100 times greater) than it would be if a quantity of high explosive with the same weight as the device causing the explosion were detonated. This definition would clearly not include inertial confinement fusion tests related to controlled fusion power plants, reactor tests, or "zero yield" tests of implosion systems. But it is much less clear what would be forbidden under such a definition. Part of the problem concerns definitions of what is included in the "explosive device," which might be a militarily useful weapon integrally attached to a considerable weight of measuring equipment or, perhaps a large mass of inert material that actually plays no role in the explosion. It is not difficult to imagine such a device that weighs 100 tons, for which the "allowable" yield might be 1 or 10 kilotons. In short, drawing the yield line at some level that is variable, depending on the nature of the explosive device, looks fraught with verification difficulties.

Another alternative is equivalent to a very low threshold treaty that allows nuclear explosions with yields up to, say, 1 ton. At such low thresholds seismic verification systems would be easy to defeat at yields substantially higher than the threshold by, for example, relatively small versions of the type of contained, low yield test facility referred to above.

A quite different approach to defining what would be forbidden and allowed by a CTBT is to forbid any explosions that produce observable fission chain or thermonuclear reactions. "Observable" could be defined as detectable by instruments in the immediate vicinity of the explosion. Such a definition would forbid tests of the inertial confinement approach to contolled fusion unless special provisions were made to allow such tests under the broad category of nuclear explosions for peaceful purposes. This definition of a CTBT would also make it possible to cheat at yields below the threshold for long range detection of explosions. This is a central issue for any type of CTBT for which no threshold yield is specified.

A starting point for exploring this issue in detail is consideration of the consequences of such a treaty if there were no cheating.

It would stop:

- Further development of all types of nuclear weapons that require tests and, in particular, pure fusion, thermonuclear, boosted fission, or high efficiency and low yield pure fission weapons.
- All nuclear weapon effects tests that cannot be simulated without use of nuclear explosions.
- Proof tests of any nuclear weapons.

It would not, by itself stop:

- Further conceptual design and non-nuclear testing of any types of nuclear weapons.
- Further production of nuclear weapons that have been satisfactorily tested.
- Proliferation of pure fission weapons based on the same principles as the early weapons produced by the nuclear weapon states, which could be stockpiled without nuclear testing.
- Nuclear weapon development and deployment by countries that are not parties to the treaty.
- Aquisition of nuclear weapons by non-national groups, including terrorists, which might or might not receive covert state support.

The foregoing summaries of the effects on nuclear weaponry of further restrictions on testing provide a point of departure for considering the relative risks of such restrictions, including the risks that one or both sides will cheat.

### Comparative Risks

No treaty is without risks, but the dominant risk lies in continued testing.

If the United States continues and the Soviet Union resumes underground nuclear testing at yields up to 150 kilotons, the nuclear arms race will enter a phase of developing radically new types of offensive and defensive nuclear weapons that will undermine the security of both.

As we have seen, the possibilities are countless, and there is no way to predict which ones may be chosen, for what purpose, by present or future military planners.

They could be low yield, highly directional warheads, placed in orbit in peacetime or "popped up" in wartime, that can destroy or disable military satellites more than 1,000 miles away, by hitting them with hypervelocity pellets, x-rays, or microwaves.

Or would they be electromagnetic noise generators that will cause Star Wars fire control systems to malfunction? Might they be tuned bandwidth directional electromagnetic pulse generators that can disable electrical equipment on the ground by explosions in high orbits? Or would they be pure fusion weapons that, at some unpredictable time in the future, remove the need for special nuclear materials to produce a full array of nuclear weapons systems? Directional blast warheads that can destroy tanks without producing any fallout are another possibility. Credible examples can go on and on.

It is not in our national security interests to encourage the Soviet Union to invent these weapons either first or second, i.e. in efforts to match U.S. inventions of the same weapons. Such weapons could undermine our confidence in our deterrent: by improving the ability of the Soviet Union to attack the eyes and ears of our security system; by helping the Soviet Union proliferate its warheads; by giving it opportunities for "decapitation" of our command and control authorities; by helping it attack our strategic forces on their bases in unpredictable ways. Obviously, the United States has a strong security interest in closing down Soviet Nuclear testing. And, equally obviously, this can only be done by closing down our own testing through mutual agreement.

The question, therefore, is only whether the U.S. Government should opt for a low-threshold test ban—at a level that can be verified from afar through technical means—or try for harder-to-verify complete test ban whose verification depends upon less standard means such as defectors, leaks, electronic intercepts etc.

My own preference would be for a complete test ban because any violations would, in any case, have limited significance in the absence of complete development and deployment of the tested weapons—and because this could, I believe, be adequately monitored to the extent that the testing *per se* might not. Furthermore, I feel that the political problems of a low-threshold test ban are at least as serious as those of a complete test ban in that fears would arise of violations of the threshold test ban of larger tests than permitted.

In any case, something must be done to protect the security of the United States and the rest of the world against these Pandora boxes of new destabilizing devices. Some kind of test ban is imperative. ■

## PAINE: ONE KILOTON THRESHOLD NOW

Christopher E. Paine

Ted Taylor has given us a valuable tour of the technological terrain in the event the weapons laboratories are directed to pursue intensive development work in the subkiloton range. However, his assessment of the theoretical possibilities needs to be tempered by an analysis of the practical engineering obstacles, overall system (as opposed to warheads) design considerations, military utility, funding constraints and political obstacles involved in developing new nuclear capabilities under a one kiloton threshold ban.

By understating or failing to analyze these factors — not the least of which is the denial of effects data under the existing ban on space and atmospheric testing — one can inadvertently lend credence to the longstanding claim of the nuclear establishment, reiterated recently by Assistant Secretary for Defense Richard Perle, that "all tests, however small the yield, could have military significance." In light of the considerable inhibitions on the use of force imposed by an inescapable mutual vulnerability to nuclear annihilation, such statements are less a description of military reality but rather a rhetorical device to set-up the argument that a Comprehensive Test Ban would be, in some meaningful sense, "unverifiable.'

It is difficult to form an opinion with respect to the purely technical aspect of Taylor's vision, because the experimental data either is not in the public domain, or remains to be generated. One is entitled to ask, however, on what basis, and on what timescale, does he project achievement of a hundredfold increase in the compression exerted by focused chemical explosions, permitting the use of gram quantity critical masses; or development of compact methods for direct initiation of fusion, or successful engineering of specially shaped and reflected critical masses which could direct a militarily significant fraction of their electromagnetic energy through an angle of one degree? Care should be taken that Taylor's discussion of these *concepts* not be construed by the press and the public as *prima facie* evidence of their feasibility from an engineering standpoint or their efficacy as part of a complete weapons system.

Indeed, a similar debate over the prospective military utility of weapons developments below the seismic detection threshold helped derail the CTB in the 1958-63 period, when this threshold was thought to be twenty times higher (in terms of yield) than it is today. Edward Teller, Albert Latter, and other CTB opponents convinced many members of the Congress, the military, and the media that continued development of low fission-yield tactical nuclear devices would lead within seven years to "clean weapons" that would revolutionize the use of nuclear weapons for defensive warfare, a possibility which Taylor now reintroduces almost thirty years later. Indeed, for Teller and Latter, "the only alternative to clean weapons" was "to avoid the use of nuclear weapons entirely." They claimed (in 1958) that "in recent nuclear tests, more and more attention has been paid to the development of such clean weapons, and most fortunately these efforts are well on

*Continued on page 14*

# A LOW THRESHOLD COULD BE EFFECTIVE AND VERIFIABLE

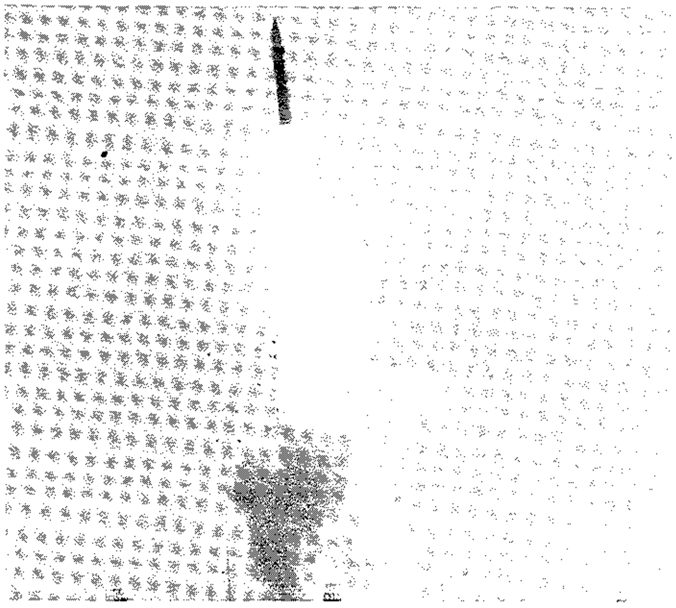
J. Carson Mark

On the surface, the notion of a Complete (or Comprehensive) Test Ban (CTB) is very attractive. However, there are considerations which suggest that a Threshold Test Ban Treaty (TTBT) might be preferable. With respect to any test-limiting treaty the U.S., definitely, and quite possibly others as well, will insist on being able to maintain assurance that the Treaty is in fact being observed. Under such circumstances, one should not set out to ban anything without a reasonable expectation that flagrant departures from the agreement could be detected and identified. This would be very difficult to do with respect to a CTB; but it could apply to a TTBT at some threshold or other.

There is, of course, active—and acrimonious—debate as to the lowest yield that may have this property with the techniques available today—some claiming that this applies down to one kiloton, or even less, while others insist that it could only apply down to some larger yield such as ten kilotons or so.

In my opinion, one kiloton in the context of a reasonable and manageable network of monitoring stations ought to be acceptable; but, to relieve a largely irrelevant squabble, for the time being, it might be better to aim at a somewhat larger value such as 3, or even 5. For the ultimate purpose of cutting back—or cutting off—the development of significant new offensive weapons such a threshold should be set as low as possible. Thus, from any given starting level, it should be planned that this would be reconsidered and lowered as techniques and experience might justify—and as paranoia may abate.

In this general connection, several points are worth noting. One is that, though the behavior of some design may be confirmed by testing at a yield lower than that intended for the full weapon yield, for devices with thermonuclear components, the factor between the full design yield which is to be certified and the reduced test yield which is to provide the certification is quite limited. Some who have commented on this have suggested a factor of two; others, about three; and a factor of five has also been mentioned. This indicates that the range is three-ish. A threshold of 3 kilotons for testing would, then, preclude the development of new weapons with yields appreciably larger than about 10 kilotons. (On this point it has been suggested that possibly the low-yield tests might have to do only with the development of new "trigger" for some much larger TN weapon; but in such case, such larger weapon will already have had to have been tested and will have been figured into the existing threat.)


*The MX missile warhead could not have been tested with a low threshold test ban.*

Another significant fact is that while the U.S. has conducted more than 800 nuclear test explosions no more than about one hundred devices have actually been carried very far towards weaponization, and only about a quarter of these are retained in the present stockpile. Evidently, a fair number of tests is required before a new design can qualify as an active weapon. Similar considerations will also apply to the USSR, which has conducted more than 500 tests. Thus, any single new test—even should it avoid detection—cannot have the effect of eroding our position vis-a-vis an opponent in any sudden or very serious way; and, indeed, cannot affect it at all before the years required to put a new weapon system in production and deploy it in quantity.

### Unlikely Possibilities

As a third point, a great deal has been said about the likelihood of someone evading an agreed limitation on tests by means of using "uncoupled" explosions, by sitting around on the *qui vive* waiting for some obliging earthquakes, by detonations fired behind the sun, and so on. None of these can be excluded as being absolutely impossible in principle. But all are so inherently awkward and/or so expensive, so high in risk content, and offer such marginal returns as to be written off as credible courses of action. Even without the political risk factor, it is extremely doubtful that we would consider such activity worthwhile. Why, then, should we suppose that others, with less money to fling about, and with the political risk factor weighed in, find that such activity had any attraction whatever?

In conclusion, as Taylor has indicated, there would still be a range of quite intriguing questions for nuclear device designers to consider even under a one kiloton threshold; and one should expect (and reconcile oneself) to the notion that testing would continue. Still, a very large part of the main point would have been gained by a low threshold treaty—that of cutting off the further development of the types of weapons which are presumably of most concern: the long-range high yield models suitable for counterforce or metropolitan targets. As an incidental point, such a TTBT would avoid the essentially unmanageable problem of attempting to stipulate or identify or control just which reasonable laboratory-type experiments were (or were not) to be free to continue legitimately. ■

# THE ADMINISTRATION'S CASE AGAINST A COMPREHENSIVE TEST BAN IS WRONG

Richard L. Garwin

Ted Taylor's article provides a very useful background for discussing test-ban policy. The Reagan Administration claims that a CTBT remains a long-term goal of the U.S., BUT the Administration says that:

1) A CTBT is not acceptable to the U.S. at this time because it is not verifiable—violations could not be detected with certainty.

2) Even if a CTBT were verifiable, so long as U.S. Security is dependent on nuclear weapons, testing must continue in order to:

2a) maintain the reliability of weapons put into stockpiles after thorough testing.

2b) Improve the safety and security of nuclear weapons.

The verifiability of a treaty depends on the definition of prohibited acts. I believe that a CTBT should permit explosive releases of nuclear energy taking place only in permanently occupied above-ground buildings, within 30 meters of personnel.

In my opinion, every one of the cited layers of the administration's "defense in depth" against a CTBT is in error:

First, underground nuclear explosions in the Soviet Union can be detected with a sufficient number of seismic stations outside the Soviet Union, supplemented by some on Soviet soil. If 22 seismometers on Soviet territory do not suffice because of inadequate propagation of high-frequency seismic signals, a larger density will be necessary in some regions. The Soviet Union has stated its willingness to accept required means of verification, and there seems no reason to believe that they would not accept 100 seismic stations if such were deemed necessary by the U.S.

Second, for nuclear weapon stockpile reliability, nuclear weapon deterioration in stockpile is prevented by assiduous non-nuclear inspection of stockpile weapons. Incipient degradation is corrected by remanufacture to original specifications. Ray Kidder of the Lawrence Livermore National Laboratory asserts that there has never been a case in which a weapon test-fired in its production version, needed a nuclear test either to detect deterioration or to correct deterioration, no matter how found.

*Richard L. Garwin*

Third, nuclear safety would indeed be improved by the adoption of insensitive high explosive (IHE) instead of ordinary explosive, and this change would require confidence nuclear-explosive testing. That this has not, in fact, been a high priority goal for the United States is indicated by the fact that only 40% of the U.S. stockpile weapons incorporate IHE.

Fourth, the security of nuclear weapons can be improved by the incorporation of successive generation of permissive actions links (PALs); I was involved with technical and programmatic aspects of the installation of the first such PALs in 1962, as I was involved in 1951-52 in the building of the first hydrogen bomb. But the benefits of new and more capable PALs can be obtained without nuclear testing.

## Will the Midgetman Warhead Need Tests?

The Administration also claims that a test ban would prevent the acquisition of a warhead for the Midgetman single-warhead ICBM, but testimony by Lt. Gen. Randolph states only that a test ban would mandate the selection of the already tested W87 MX warhead. The Administration asserts that the MX warhead cannot be definitively chosen for the Midgetman because of the as-yet unspecified shock which must be resisted by the warhead in a mobile launcher subject to nuclear attack. But the decision can indeed be made now, by putting the requirement on the yet-to-be-defined mobile launcher to mitigate the environment for the warhead. After all, when NASA launches senators or other astronauts into orbit, they do not redesign the astronauts; instead they provide an environment that is tolerable to the person.

Taylor is right in wanting a CTBT to dampen a U.S.-Soviet technical competition in new weaponry which may increase our virtuosity, but not our security. But, in addition, I believe that a CTBT is essential to provide the moral and practical basis for the community of nations to bar testing of nuclear weapons by nations that wish to acquire nuclear weapons, and to enforce such a ban by the strongest possible measures. A Threshold Test Ban Treaty, no matter how low the threshold, legitimizes nuclear tests and would not provide the moral basis for opposing testing and acquisition of nuclear weapons by other nations. In practice, a low threshold would create unending argument about compliance, unless every sub-threshold test were monitored with local cooperative means.

If a CTBT could not be implemented immediately, rather than a threshold for a period of years, a combination quota and threshold could be considered, providing constraints additional to those imposed by the nuclear testing agreements already in existence. For instance, a declining quota of three tests in the first year (each of yield below 15 KT); two tests in the second year with yield below 1 KT; and no tests thereafter would achieve most of the benefits of an instant CTBT and might be easier to adopt. ■

*Continued from page 11*

their way to success." The latter statement was misleading in the extreme.

No sooner had the movement toward a CTB been blunted and channeled into the Limited Test Ban, than the pretense of any near term prospect of "pure fusion" weapons was dropped, and even the development of low-fission yield "enhanced-radiation" devices was placed on the back burner, in deference to achieving further incremental improvements in the yield-to-weight ratio of medium yield offensive weapons. When enhanced-radiation weapons finally reached the production stage in the late 1970's, their actual deployment was severely limited by both political considerations and a lack of operational military utility.

Today's proponents of a complete ban on further nuclear explosive testing must take care that they do not contribute to a repetition of this history by overstating the likelihood or strategic significance of results to be obtained from further low-yield nuclear tests. While such dire forecasts can serve to emphasize the urgency of a complete CTB, they can also serve to undermine it by exaggerating the strategic advantages to be obtained from cheating.

On a related matter, Taylor refers, with perhaps a hint of disapproval, to "a widely held view in Congress" in support of a low-threshold *treaty*. The only reliable indications we have of Congressional sentiment in this area are nonbinding Senate and House votes in favor of *CTB negotiations* and an August 8 House vote of 234—155, later discarded in conference, mandating a *one-year cutoff in funding for the conduct of tests above 1 kiloton.* This vote was regarded by its sponsors not as a substitute for a negotiated CTB — in the unlikely event such negotiations suddenly materialized under the current Administration — but rather as a way to hold the line on U.S. nuclear tests, respond positively to the Soviet test moratorium, and stimulate progress on the verification issue.

In the view of the amendment's sponsors, the thorny verification problems posed by subkiloton tests, to which Taylor refers only in passing, cannot be resolved through the legislative process. But the "Aspin-Gephardt-Schroeder" amendment did in fact break new legislative ground by mandating *reciprocal conditions* for implementation of the proposed moratorium on tests above one kiloton. This particular route toward a CTB was chosen because an informal political and technical consensus had emerged regarding the ability of in-country seismic monitoring networks to detect even decoupled explosions above that threshold. The amendment further simplified the monitoring task by requiring that each side carry out any permitted subkiloton explosions in "strong-coupling" rock within a single "designated test area." This condition, in conjunction with thorough calibration of the networks monitoring each test site, should alleviate Taylor's concern about endless disputes over compliance with the one-kiloton threshold. Even if yield estimation techniques do not improve beyond the present accuracy of 30%, neither side should lose much sleep over deviations on that scale at such low yields.

In light of Taylor's analysis, procedures for coping with large chemical explosions, fusion experiments, "zero-yield" or ton-range nuclear tests, and other problems involved in constructing a complete ban obviously deserve increased attention from CTB proponents, particularly those who maintain that the subkiloton range is a "Pandora's" box crammed with "third generation" nuclear weapons. But these concerns should not disrupt consensus on prompt implementation of a one kiloton threshold agreement along the lines established by the House vote. Consensus on a partly flawed but nevertheless worthy and *immediately plausible* goal is hard enough to establish within the American political system without adding to it the burden of attaining perfection. In defense politics, especially, the best must not be made the enemy of the good, because the merely good may be all that the current and future state of bureaucratic politics and international confidence will allow. Moreover, the House amendment's sponsors were advised by knowledgeable scientists that weaponization of present nuclear directed energy concepts would require significant testing above the 1 kiloton threshold, presumably because predicted efficiencies of NDEW devices do not approximate those implied by Taylor.

The historical record tends to support the hypothesis that the prospect of attaining a Comprehensive Test Ban is governed by interaction in the political arena between: available monitoring capabilities, the perceived value of pending and prospective developments in nuclear weapons technology, and fluctuating views of national leaderships regarding the psychological value of explosive testing in underscoring each side's willingness to use nuclear weapons to defend its national security interests.

Of these factors, I believe the last mentioned to be controlling. For example, what if either side were to adopt the view that nuclear devices are not *weapons* which must meet traditional (and ever escalating) military criteria [reliability, accuracy, survivability, mobility, security, and safety], but rather instruments of retribution whose sole purpose is to dissuade any nation from actually employing nuclear weapons against another? In this case, any nuclear power could unilaterally forego nuclear explosive testing altogether and, given adequate attention to other aspects of its deterrent force, still be secure in the knowledge that it possessed a "credible" deterrent against nuclear attack.

But such a "minimum deterrent" mission for nuclear forces on either side could be satisfied with a compact force

*Christopher E. Paine*

### THE ERA OF THE LIMITED TEST BAN TREATY

**Since late 1962, when the Limited Test Ban Treaty banning all nuclear tests except underground took effect:**

- **There have been more than 950 underground nuclear tests, at least 530 by the United States and 420 by the Soviet Union. The yields of these tests were limited, since 1976, to not more than 150 kilotons by the signed, but not yet ratified Threshold Test Ban Treaty. Claims by the U.S. government of several violations of this threshold have been refuted.**
- **Although the world's stockpile of nuclear warheads has remained, at a total, in the vicinity of 50,000 for the last decade or so, the U.S. and the U.S.S.R have made major changes in their nuclear weapons delivery systems, notably the introduction of multiple warheads on individual missiles (MIRV), air and sea launched cruise missiles, and, for tactical uses, enhanced radiation weapons (neutron bombs), and several dozen other types of weapons.**

perhaps one-tenth the size of present strategic forces, but still large enough to deter either side from indulging in the illusion of a sudden "breakout" of defensive forces. Since the nuclear testing *apparats* would no longer be called upon to support the "credibility" of nuclear war fighting postures by generating incremental or "revolutionary" improvements in military characteristics, the problem of defining and monitoring "militarily significant tests" at very low yields would evaporate, and the bulk of the nuclear weapons establishment could be turned out to pasture. One could simply sign an agreement which relied on existing national monitoring capabilities and discounted the "risks" posed by undetected cheating at low-yields as inconsequential for national security.

Forecasts of technical breakthroughs forever poised to spring from beneath a steadily declining detection threshold have long been used by CTB opponents to foster demands by unwary politicians for an "ironclad" verification system, whose specifications are then obligingly drawn-up in a manner that somehow always manages to exceed the carrying capacity of prevailing Soviet-American relations.

The way to short circuit this purposeful Catch-22 is by reconciling the technical capabilities of a monitoring system that the Soviet Union is likely to accept with majority political perceptions of the military significance of testing under various yield thresholds. The recent House vote suggests that such a consensus is indeed attainable in support of a low threshold ban, and Gorbachev has indicated that he is willing to approach a Comprehensive Ban through interim restraints if these restraints represent meaningful steps toward a CTB rather than a spurious mutual ratification of each side's nuclear test program. Whenever technical and political conditions warrant, this low threshold can be further reduced to approximate the comprehensive ban which has eluded our grasp for so long. ■

## ADMINISTRATION IN DISARRAY ON ARMS CONTROL

Since our last report which sought to support the President on zero-ballistic missiles, the Administration has:

- changed the position to one of holding onto a small number of ballistic missiles, (if you believe the State Department);
- abandoned the proposal as unrealistic, (if you believe the Arms Control and Disarmament Agency);
- characterized the proposal as "not operational at this point," (if you believe unnamed White House sources);
- left the proposal out of a Presidential speech.

But if you believe Richard Perle, the proposal is still on the table although, he says, it never involved eliminating British, Chinese, and French ballistic missiles.

In the light of congressional reaction, and that of the Europeans—who, predictably, are opposed to any significant change whatsoever, lest they have to think through its implications—zero-ballistic missiles seems to have died aborning.

More generally, this Administration may have lost its ability to negotiate any significant arms control at all.

Another obstacle to the Reagan Administration's progress in arms control of any kind is its bad manners. It has tended to alienate the whole strategic community outside its own personnel including the Congressional members.

When Richard Perle, for example, heard House Armed Services Committee Chairman Les Aspin complain that the administration had not "brought home the bacon in six years," he seized the occasion, in written prepared remarks, to indict all of Congress as better at dealing with "pork" but only good at doling it out. He made a number of sarcastic and patronizing remarks about previous Congressional work in arms control and lectured the Congress that "no agreement" could be better than agreements "inimical to our security."

With this sort of style, even an unimpaired Administration is unlikely to get very far in securing a consensus for any arms control proposal at all.

One can never be sure, of course. The Administration might change its key players, as so many are urging it to do and the situation might then get better—if it did not get worse. Also the President might feel obliged to get some kind of agreement, much as President Nixon sought the Threshold Test Ban Treaty when he was in political trouble over Watergate.

It may be that America is, politically speaking, insufficiently stable to negotiate much in the way of arms control agreements. There are narrow windows of political opportunity between elections. The high visibility of all negotiations, the two-thirds rule in the Senate for treaty ratification, and the ease with which suspicion of adversary cheating gets transformed into a debilitating certainty all cause difficulties—not to speak of the problems of getting Alliance agreement and the real difficulties which the Soviet Union provides to agreement. We badly need some kind of on-going leadership in this field that transcends the Administration-by-Administration approach upon which we have been relying. -JJS

## ABOUT THE CONTRIBUTORS TO THIS FAS REPORT

**_Theodore B. Taylor_: For twenty years, after receiving his B.S. in 1945 from the California Institute of Technology, Ted Taylor worked on the design of nuclear weapons, on nuclear space propulsion and on nuclear weapons effects. He rose to the position of Deputy Director (for Science) of what is now the Defense Nuclear Agency in the Pentagon. Dr. Taylor's experience in the Defense Department from 1964-1966 left him disillusioned and alarmed about the prospects for control of the arms race in general and, especially, about the danger of proliferation and terrorism. His career was chronicled in the _New Yorker_ magazine in December 1973 under the title "The Curve of Binding Energy." Later he formed the NOVA Corporation to work on renewable energy resources.**

**_Richard Garwin_: Joined IBM Corporation in 1952, and is presently the IBM Fellow at the Thomas J. Watson Research Center, Yorktown Heights. Richard Garwin is famous for accomplishments in science and public policy in a dazzling variety of fields. He has made scientific contributions in the design of nuclear weapons, and in instruments and electronics for research in nuclear and low-temperature physics.**

**_J. Carson Mark_: Served as Head of the Theoretical Division of the Los Alamos Laboratory after World War II (he replaced Hans Bethe), and worked at Los Alamos until his retirement in 1973. He has extensive direct experience in the area of Dr. Taylor's paper.**

**_Christopher E. Paine_: A Harvard graduate and former staff member of FAS, Mr. Paine worked, until recently, with Congressman Ed Markey on the staff of the Subcommittee on Conservation and Power. In this capacity, he played a leading role in the design and passage of the Summer, 1986 one-kiloton threshold nuclear test ban proposal.**

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