Paul Doty

A NUCLEAR TEST BAN

Nuclear detonations are constant reminders of mankind's capacity for violence. It is not surprising that people and governments conclude that if this symptom of supreme violence were exorcised, the risk of nuclear war itself would diminish. Even though this position has psychological force and strong popular appeal, it bears deeper examination.

At issue is whether the single, radical step of ending all nuclear weapons testing, given the uncertainty of detecting lower-yield tests, is the best route to stopping the qualitative strategic arms race. Can such a step be pursued as an independent goal without linkages to other kinds of arms control and disarmament? Or are there more promising ways of restraining testing than its total elimination? In addressing this last question we need to examine the essential issues in the current debate and analyze current approaches. Then we can sketch a phased approach to a regime that would respond to most of the issues raised and secure the traditional goals of a comprehensive test ban (CTB) treaty, provided that it is embedded in a broad commitment to arms control.

II

The Soviet government's position, from the first serious discussion of this matter in the U.N. Disarmament Commission in 1957 until the Reykjavik summit in late 1986, was that banning nuclear tests should be negotiated independently of other arms control measures. In 1957 this took the form of demanding a temporary moratorium (to allow negotiation of a total ban) as an immediate step, independent of disarmament. General Secretary Mikhail Gorbachev took the same tack in July 1985 when he urged immediate negotiation of a CTB during a testing moratorium that the Soviets were about to initiate. It was evident that the Soviets felt that such a ban could be arrived at "in a matter of months." As late as Septem-

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Paul Doty is Director Emeritus of the Center for Science and International Affairs and Mallinckrodt Professor of Biochemistry at Harvard University.

ber 1986 Gorbachev asked that "talks in any form—bilateral, tripartite or multilateral, and moreover without linkage to any other questions—be resumed or started."

Yet at Reykjavik, Gorbachev brought the negotiation of a CTB into relationship with the three-part arms control proposal: 50-percent reductions of strategic forces, the near elimination of intermediate-range nuclear forces and limitations on testing in the Strategic Defense Initiative (SDI) program. He offered to drop the prior demand for immediate cessation of all nuclear tests, so long as negotiations proceeded on scaling down the number and yield of tests over time, maintaining however the goal of complete elimination. This proposal brought the Soviet position in range of the U.S. position, i.e., that a CTB is desirable as a long-term goal when considered in the context of broad, deep and verifiable arms reductions and other measures.[1]

The U.S. position was also modified in time for the Reykjavik summit.[2] President Reagan proposed to ask the Senate as the first order of business in 1987 to give its approval to two unratified treaties, the Threshold Test Ban Treaty of 1974 and the Peaceful Nuclear Explosions Treaty of 1976, if the Soviet side agreed to additional verification measures. If the Soviets did not agree to additional verification measures, the President would nonetheless seek Senate approval, but with the reservation that the treaties not go into effect until "they are adequately verifiable." After this step was accomplished the two sides could immediately begin parallel negotiations on reducing and ultimately eliminating nuclear weapons and nuclear testing.

A tentative accord embracing the new views on both sides seemed to be within reach at Reykjavik but fell short over the SDI problem and the U.S. insistence on not reaching the complete ban on tests until nuclear weapons were eliminated. Thus the two sides have moved closer—from outside to inside a large negotiating arena—but signs of rapid progress are lacking. The recent offer to negotiate intermediate-range nuclear forces independently does, however, hold promise for possible movement in the test ban area.

Aside from resonating with popular support for a ban on

[1] *Arms Control Issues*, The Arms Control and Disarmament Agency, Feb. 8, 1986; *Gist*, Bureau of Public Affairs, Department of State, May 1986; see also *Background Briefings on Test Ban Treaty*, The White House, Washington, July 20, 1982.

[2] *The New York Times*, Oct. 11, 1986.

nuclear testing, the Soviet interest lies deeper. As Soviet academician Evgenii Velikhov put it:

> Ending [nuclear testing] would facilitate the achievement of a concrete objective—the prevention of the development of new destabilizing weapons—as the experience of preceding decades shows that development and improvement of new nuclear weapons are the main sources of instability.[3]

Furthermore, the Soviets realize that domestic reform must have first priority; hence they wish to dampen the arms race by a CTB and other measures so as to direct their energy and resources more explicitly to their newly felt needs. It is also possible that the Soviets believe they are further advanced in weapons design and wish to preserve their advantage.

U.S. interests have been divided. Although all U.S. administrations since Truman's have sought to negotiate a CTB (and the negotiations in the Carter period made progress), the current U.S. Administration holds that a CTB

> must be considered in the context of a time when we are less dependent on nuclear deterrence than we are now to ensure international security and after we have achieved broad, deep and verifiable arms reductions, substantially improved verification capabilities, expanded confidence-building measures, and a greater balance in conventional forces.[4]

A majority of the U.S. Congress, however, appears to accord the CTB a higher priority. On August 8, 1986, the House approved an amendment to the defense authorization bill, by a ratio of three to two, that would deny funds for nuclear testing for one year subject to certain provisions. This initiative was withdrawn in order not to encumber the President at the Reykjavik summit, but in 1987 the Democratic-controlled Congress is likely to insist with greater vigor on some progress in diminishing nuclear testing. Thus the test ban debate, both domestic and international, seems destined to continue.

III

If all the difficulties associated with a CTB[5] could be reasonably solved and if all relevant nations subscribed, the most

[3] *New Times* (Moscow), in English, No. 40, October 1986, pp. 6–8.

[4] *Loc. cit.*, footnote 1.

[5] CTB is used here in the literal sense of "comprehensive," not being restricted to the widespread impression that this is equivalent to "complete," but addressing all issues related to its goal.

direct consequence would be an end to further development of significant new types of nuclear weapons, that is, warheads and bombs, but not total weapons systems including launchers. If this agreement were part of a far-reaching arms control regime as both the U.S.S.R. and the United States envisage it, this would signal a remarkable and historic change in the perceived role of nuclear weapons.

A CTB, however, would not itself have an immediate direct effect on nuclear forces. The average period for developing new nuclear weapons is long—often eight to ten years from conception to deployment. Prior to such a new treaty coming into effect there would undoubtedly be a hurried completion of weapons near the end of their development cycle. But, over time, new weapons systems would have to be developed around existing warhead designs. Even this kind of development would probably slow if numbers of weapons were also being reduced. A CTB would by no means end the arms race, but it would put an end to developing new weapons. With respect to SDI the non-nuclear weapons development would, of course, proceed. Existing nuclear warheads could be used for terminal defenses if needed. But it would stop initial development of one potential component, the nuclear-pumped X-ray laser; its full development, involving an estimated 100 tests or more,[6] would require testing in space, which is prohibited by the Limited Test Ban Treaty, and its deployment in space, which is prohibited by the Outer Space Treaty.

Thus a CTB could be expected to result in a gradual downturn in the qualitative arms race. While the development of new weapons systems would not be stopped, they would not carry new weapons. Consequently, the commitment to the present pace of developing weapons systems would probably decrease and that part of popular opinion that reacts negatively to any "new" developments in the nuclear weapons field would be accommodated. There would remain the arguments of test ban opponents that it is only under nuclear testing that the megatonnage of the nuclear arsenals has actually diminished and safer weapons have been developed. The counterargument is that current nuclear weapons technology has most probably reached a plateau. If this is true, then further testing would not result in comparable, constructive innovations.

[6] See quotations from H. Bethe and H. Dewitt in *Federation of American Scientists Public Interest Report*, Washington, D.C., December 1986, pp. 5, 6.

A CTB treaty would, furthermore, represent a decision by the superpowers to complete long-standing unfinished business promised in both the Limited Test Ban Treaty of 1963 and the Nonproliferation Treaty of 1968. In doing so the arguments for other nations to develop their own nuclear weapons would be weakened; nonproliferation arguments could be brought to bear without having to concede that the superpowers had not lived up to their promise.

But the chief consequence of a CTB is likely to depend on whether it is an essential component of a broad approach to arms control. It is difficult to see a CTB being negotiated and surviving in isolation; it is also difficult to see a broad agreement on reductions in nuclear weaponry of both strategic and intermediate ranges, together with some resolution of the strategic defense problem and possibly conventional force reductions, while nuclear tests proceed apace. There is both a benefit to this integration and a cost. The benefit is that many more trade-offs are possible when negotiating a larger package; the cost is that the CTB negotiation is hostage to reaching agreement on much larger issues. Nevertheless, the technical aspects involved in negotiating a CTB treaty are rather isolated from the issues affecting the larger arms control menu. Consequently, such negotiations could proceed independently toward an agreement that would become part of a much larger package when such a union could be reached. We turn then to the special difficulties that confront the negotiation of a CTB treaty.

IV

Many see the principal factor weighing against a CTB to be the loss of reliability that would occur due to the aging of the nuclear weapons stockpile or to undetected defects in the design of some weapons. With the passage of time, corrosion and deterioration of components can reduce the yield of a weapon or even cause it to fail completely. Also, existing weapons may have to be put in service under conditions not anticipated at the time of their certification, as would be the case if weapons designed for fixed launchers were used with mobile launchers traveling on rough terrain.

Most monitoring for reliability does not involve nuclear detonation, but rather nondestructive procedures requiring disassembly or testing with the nuclear material removed. Public testimony from the laboratories indicates that detonation even at reduced yields is rarely done. There are claims that detonations have been essential in a few cases,[7] but even this has been disputed: it has been pointed out that the weapons in question were not adequately tested prior to stockpile entry or that subsequent testing was not actually required to remedy the fault.[8]

Two policies in particular contribute to this conflict over reliability. One is the traditional approach to weapons design in the weapons laboratories. Generally, new nuclear warheads are designed for each new delivery system so as to optimize the weapon for its mission. This puts a premium on sophistication and maximal yield-to-weight ratios. By working at the margins in order to improve optimization there is less slack for tolerable changes as the weapons age. Less sophisticated, more robust weapons could be produced but at the cost of less yield for the permitted weight. Consequently, it appears that weapons of simple but less efficient design that could also be easily maintained indefinitely have not been developed. Interestingly, this practice was not followed even under those administrations that favored a CTB, perhaps because it would mean higher costs for a given yield.

Extremely high standards for weapons certification can also create an artificial requirement for additional reliability testing. Overall reliability of weapons systems performance involves many factors beyond the warhead detonating at a specific yield: the issue and receipt of the command, the carrying out of the proper launch sequence, the correct flight performance and the accuracy at target. When all these other sources of uncertainty are taken into account, a current study concludes that the overall performance of the systems would not be significantly degraded if the yield were uncertain by a factor of two.[9] For example, accuracy is much more sensitive than yield: improvements in accuracy of delivery by only 30 percent could compensate for a change in yield by 100 percent. Viewed in this way some relaxation in the certification standard could be justified, thus diminishing further the need for certain reliability tests.

The reliability of weapons takes on a different aspect if one

[7] J. W. Rosengren, "Some little-publicized difficulties with a nuclear freeze," R&D Associates, Marina del Rey, Calif., October 1983; P. S. Brown, *Energy & Technology Review*, Lawrence Livermore National Laboratory, September 1986, pp. 6–18.

[8] R. E. Kidder, *Report UCID-20804*, Lawrence Livermore National Laboratory, June 1986.

[9] S. Fetter, manuscript in preparation, Center for Science and International Affairs, Harvard University, 1987.

assumes that a CTB may last for many decades and that reliance on nuclear weapons for deterrence continues. In that case remanufacture would probably be necessary. This would require that the supply of all the components be maintained as well as the skills involved in assembly. Over time this would amount to a demanding requirement, but seemingly one that could be met within present budget scales. Meanwhile, for the nearer term, there would be much to do: more intensive monitoring of stockpiled weapons, disassembly and checking of randomly selected weapons and, when necessary, their remanufacture. Such activities would become the basis of ensuring stockpile reliability under a CTB.

Whether some allowance would need to be made for nuclear testing to ensure reliability is likely to remain unresolved. It is difficult to discount all past claims that some reliability testing is necessary, as well as claims that it may be required at future times. If a CTB is to last a very long time, situations not previously encountered may arise that would justify some testing. If deep reductions in weapons numbers proceed, then the reliability of the remaining weapons increases in importance. In any event, however, the total number of such tests required would be very small in contrast to the much larger number required for new weapons development.

V

Verification has been a central issue in test ban debates and agreements since the 1950s. The dominant question has been: What is the lowest practical threshold of underground tests at which detection could be made with sufficient probability that violations would not lead to militarily significant advances? The Limited Test Ban Treaty of 1963, banning testing in the atmosphere, set no threshold for underground testing. The requirement that the tests be underground placed a practical limit on them of about 5,000 kilotons (kt) for isolated locales and about 1,000 kt for testing within a 100 to 200 mile range of urban areas. Actually, the great majority of tests was below 300 kt.[10] Since 1974 the Threshold Test Ban Treaty, unratified but nevertheless observed, has constrained underground explosions to a maximum of about 150 kt.

Most nuclear tests are of such a yield that high-quality seismic

[10] L. R. Sykes and D. M. Davis, *Scientific American*, January 1987, pp. 29–35.

detection systems with sufficient stations properly located can detect and identify tests and estimate their yield rather well. Obviously, the lower the yield the more difficult this becomes, and at sufficiently low yields seismic detection fails. Although this failure sets in at very low yields compared to the usual testing range, it does exist. Consequently, a *total* ban on nuclear tests cannot be verified.

Many proponents of a CTB fail to deal with this point. Some imply that improvements in seismic measurement of yield will allow verification of tests down to such a low value that any that did occur would not be militarily significant. This may be so in a decade or two, provided that there is very considerable cooperation among the contending parties and a willingness to invest in building and maintaining an expensive seismic detection system. Meanwhile, a treaty would have to specify a threshold; such a treaty would be known as a low-yield threshold test ban treaty. Policymakers naturally want to know the lowest yield that is reasonably verifiable with a specified seismic detection system. There is no simple answer because the translation of seismic measurements to explosive yield is complicated by several factors.

First, seismic measurements provide four kinds of information: (1) the detection of underground earth movements arising from earthquakes or explosions, (2) the discrimination between earthquakes and explosions, (3) the approximate location and depth of the explosion and (4) an estimate of its yield. The seismic waves from an explosion are of several kinds, including P and S waves. These two waves move throughout much of the earth, and are detectable at many thousands of miles from the explosion. A similar pair of P and S waves travel shorter distances and others travel at the surface. The amplitude (magnitude) of the waves is related to the yield of the explosion. By coordinating the arrival times of the waves at different seismic stations, the site of the explosion can also be located.

In addition, the waves display a range of frequencies. Until the 1960s most seismology concentrated on analyzing only one or two of these waves and in a narrow frequency range. But since then the seismic data has been examined in more detail and more sophisticated seismic stations have been tested. As a result much more seismic information is becoming available and the capability of seismic detection is certain to improve. Much of this promise is not yet clearly demonstrated; consequently, controversy continues between those who make judgments on the basis of existing stations and practice and those who take into account emerging improvements.

As a result of this changing state of the art, three different kinds of seismic detection systems are currently discussed for use in verification. One is the National Technical Means (NTM) system, which consists of seismic monitoring stations in the United States and abroad (though not in the Soviet Union), supplemented by other data-gathering systems. It is this system that provides the present U.S. monitory capability. The Soviet Union has a comparable capability. The second system, known as a "simple system," consists of the NTM system plus ten single seismometer stations to be placed in the Soviet Union and in the United States, as tentatively agreed in the 1977–80 CTB negotiations. The third system envisages a dramatic improvement that is possible if each of the single seismometers is replaced with an array of seismometers located a few kilometers apart and the number of stations is increased from 10 to 30.

Computer simulation indicates that the sensitivity of the "simple system" would be twice that of the NTM system and that the enhanced array system would be ten times as sensitive as NTM.[11] If there were no complications in exploiting these sensitivities, all of these systems could detect explosions carried out in hard rock down to about one kiloton or less, and a CTB could become a reality. But several complications intervene in crucial ways to degrade the accurate translation of seismic measurements into explosive yields.

Earthquakes obviously present a problem for all seismic detection. They occur continuously within the earth and give rise to seismic waves, though of a somewhat different nature than those generated by explosions. Nevertheless, since the occurrence of earthquakes increases sharply at lower magnitudes it follows that there will be a level for nuclear explosions below which the seismic signal from the explosion will be overwhelmed by the seismic signals arising from small earthquakes. At some lower limit it is not possible to discriminate between the different character of seismic waves generated by explosions and by earthquakes. The limit depends on the number and distribution of the seismic stations in the monitoring network.

Thresholds are higher in seismically active regions because of the higher seismic background from earthquakes. For ex-

[11] *Energy & Technology Review*, August 1986, p. 36.

ample, the seismic signal from a test of one kiloton in hard rock competes with comparable or larger signals from about 20 shallow earthquakes per day worldwide, or nearly one per day within the Soviet Union. Only a few detection stations would pick up the signal. But with the enhanced array system, and taking into account the distribution of seismic activity, it is likely that such signals could be correctly interpreted. By contrast, the present NTM system could not deal reliably with such an event.

A second major factor that degrades the utility of seismic systems is the suppression of the signal that occurs when a nuclear explosion occurs in any medium other than hard rock. When an explosion occurs in hard rock with little surrounding empty space, the force of the explosion is directly coupled to the rock and the maximum seismic wave is generated. Such an explosion is said to be maximally coupled. In this case the wave measurements can be related directly to the yield of the explosion. However, when the medium surrounding the explosion is sediment, or softer or pulverized rock, the seismic signal is muffled and can be considerably reduced. This is called reduced coupling; the same wave signals as received from explosions in hard rock then correspond to higher yields.

The test sites in the Soviet Union and indeed most of its territory consist of hard rock. The Nevada Test Site, where almost all U.S. testing is done, sits above a region of molten rock, which dampens the seismic waves. Consequently, the geological nature of the test site area must be known in order to make accurate estimates of yield. This kind of information can best be obtained by calibration tests, i.e., setting off explosions of known yield at such sites. Such tests also allow correction for the variations in the decay of the seismic waves as they pass through heterogenous structures within the earth.

The third problem in seismic detection is the reduced coupling, or decoupling, that can result from setting off the explosion in a large underground cavity. If the cavity is large enough the seismic signal might be reduced as much as 10 to 100 times (using the P wave magnitude). However, this form of deception is impractical except at very low yields. The mere construction of such a large underground hole is difficult, expensive and visible to surveillance. Moreover, the possibility that the explosion would trigger a collapse into the cavity and thereby become clearly visible at the surface would further increase the risk of detection, as would the possible leakage of radioactivity.

In practical terms it is reasonable to assume that no party would make deep underground excavations larger than the Great Pyramids (100,000 cubic meters). This would limit cavity-decoupled explosions to less than two to ten kilotons. Hence, like earthquakes, cavity decoupling is of concern only at the low end of the yield scale.

It should be noted, however, that the variance associated with estimated yields increases as the yield diminishes, especially below ten kilotons, and the CORRTEX method (see p. 763) is of no use in this range. This further complicates the verification of yield in the one-kiloton range, but it could be handled by agreeing on a larger tolerance in estimated yield values.

The threshold problem can now be seen in better perspective. With the present NTM seismic system, allowing for decoupling at low yields, the lowest threshold for reliable verification is about ten kilotons; it is at least five times lower without decoupling.[12] These limits would be lowered further if the simple system or the enhanced array system were in place. Still further improvement might come from processing the higher-frequency seismic waves, since these are now found to be less affected by decoupling. A specific estimate of a reasonable threshold is given by Dr. W. J. Hannon of the Lawrence Livermore National Laboratory, who concludes that

> networks with 15 high-quality array stations in the Soviet Union could detect events with seismic magnitudes of 3.0 (and down to 2.4 in localized regions). Such networks are thought to be capable of detecting cavity decoupled explosions with 3 to 10 kt yields with 90% confidence.[13]

Other seismologists argue that the threshold would be as low as one kiloton.

To summarize in a conservative way: without cavity decoupling, with restriction to known test sites and with calibration tests, the present NTM seismic system could deal adequately with a ten-kiloton threshold, the simple system with a five-kiloton threshold and the extended array with a one-kiloton limit. Decoupling could raise these thresholds but, as noted above, decoupling is impractical except below the five-kiloton range; furthermore, a prohibition on decoupling could be adequately verified.

[12] L. R. Sykes, Hearings, U.S. Senate, Committee on Foreign Relations, June 16, 1986.
[13] W. J. Hannon, *Science*, Jan. 18, 1985, pp. 251–257.

In considering these matters, an important distinction must be made between the degree of confidence required to identify a violation of potential military significance as opposed to identifying the occurrence of a single test. One test above the threshold is unlikely to lead to a militarily significant development, although it could be used to check the reliability of a slightly redesigned weapon. A militarily significant event would be the detection of a series of tests, which would be required for development of a new weapon. For this purpose 90-percent confidence in detecting a single test is much more than is needed because only one violation within a series need be detected. For example, a confidence level of only 30 percent for an individual test would provide an overall confidence level of 90 percent for identifying at least one violation in a series of seven tests. If this standard were to be adopted, a threshold of ten kilotons could be lowered to five kilotons.

Yet opinions divide sharply on this issue. If the object is to maximize the likelihood of detecting a single test in violation of an agreement, then a higher threshold is desirable. If, however, the aim is to detect nearly any violation that could be militarily significant, a lower threshold would be justified.

In sum, the selection of a threshold for a low-yield threshold test ban treaty is not simple. It depends on the quality, affordability and negotiability of the seismic system to be employed, the system's ability to reject the random noise of earthquakes, information about test sites, calibration tests of verifiable yield, an assumption about possible use of cavity decoupling, and the aim of the threshold limit. Moreover, it should be anticipated that the sensitivity of seismic systems will improve in the future, perhaps to the point where all militarily significant tests can be banned.[14] Clearly, such a selection involves a careful fusion of technical, military and political judgments.

VI

With the foregoing evidence that a threshold in the range of ten kilotons is verifiable with the NTM or the simple seismic system, it may seem surprising that there has been such an intense debate over whether or not the U.S.S.R. has been testing above the much higher 150-kt threshold established in

[14] It is relevant to note, however, that at thresholds below about one kiloton, the occurrence of chemical explosions connected with mining and construction may introduce so many false signals that still lower thresholds would not be practical.

the Threshold Test Ban Treaty of 1974. Aside from certain political motives, two technical factors are involved. One has to do with the uncertainty over the geological media at the Soviet test sites, since this affects the magnitude-yield relation. Over recent years the evidence has grown that the Soviet tests are less muffled than those at the Nevada Test Site, and a correction has reduced the estimated yield of Soviet tests. Recently the Central Intelligence Agency proposed a 30-percent reduction in yield estimates.[15] This noticeably reduced the number of Soviet tests estimated to be above 150 kilotons.

Yet various U.S. government spokesmen continued to allege that some events remained well above the threshold in violation of the unratified treaty. To understand this claim one must take into account the second factor affecting yield estimates—random error associated with any yield estimate. To illustrate this point, assume that 20 tests of precisely 150-kt yield were detonated at the same site in the U.S.S.R. The estimated yields of these tests determined by our NTM system would spread over a band of values. (This spread would be narrower with more advanced detection systems.) At present this spread, or variance, is taken to be such that there should be a 95-percent probability that the measurements of yields from a 150-kt test would fall within the range of about 75 to about 300 kt. If this is the variance associated with current measurements then it is clear that estimates as high as 200–300 kt could occasionally be obtained from Soviet testing at the 150-kt limit. It is equally true that such results could come from Soviet tests above the threshold. Thus there is currently an indeterminacy with respect to measured yields of tests: this can be narrowed by use of more sophisticated seismic systems with some stations located within the testing countries, but it cannot be eliminated.

In three successive Noncompliance Reports to Congress, which are required by law, President Reagan has stated that the U.S. government has found that a number of Soviet tests constitute a likely violation of legal obligations under the Threshold Test Ban Treaty. The Arms Control and Disarmament Agency defended this position in May 1986 by stating that "the claim of likely Soviet violation was not based solely on seismologically determined . . . . yields but on the full scope of data and analyses available." Most professional seismologists disagreed with this finding on the basis of available seismolog-

[15] *The New York Times*, Apr. 2, 1986, p. 1.

ical data. Their views and those of government witnesses were presented at hearings before two House committees in 1985 and the Senate Committee on Foreign Relations in 1986. Dr. Roger Batzel, director of the Lawrence Livermore National Laboratory, testified: "Based on our assessment of the relationship between yield and seismic magnitude for the Soviet test site and the pattern of Soviet testing, we have concluded that the Soviets appear to be observing a yield limit . . . consistent [with the threshold test ban]."[16] Moreover, this treaty allowed for occasional small breaches of the limit because weapons designers cannot predict with great accuracy the yield of weapons before testing. There remains a difference in views within the U.S. government. But it appears that the estimates of the yields of Soviet tests above 150 kilotons that can be cited as violations can also be explained by the variance of U.S. measurements plus the possibility of rare exceptions allowed by the treaty. The seismological and other evidence needed to determine which explanation is correct is either nonexistent or not in the public domain.

The U.S. Administration has sought to deal with these differences by introducing new technology. Since any tests above 75 kt may, due to variance in the estimates, occasionally register as high as 150 kt, it has asked the Soviet government to allow U.S. scientists to use a technique known as CORRTEX at Soviet tests to provide more precise yield estimates for tests in the 75 to 150 kt range. The Soviet response has been negative, perhaps because the method is highly intrusive. (It requires lowering an apparatus into a drilled hole only a few feet from the hole containing the nuclear weapon.) Furthermore, agreeing to this procedure locks the Soviet government into a particular interpretation of what a threshold means. At issue is whether to treat the 150-kt threshold as the average value about which tests at that yield would be registered, or if 150 kt is to be regarded as a wall beyond which no yield estimates should be allowed. In this case the maximum yields of the tests that one side could carry out are at the mercy of the variance in the seismic system used by the other side.

Whether such preoccupation with fine-tuning the yield estimates is justified depends on how wide a deviation can be tolerated without it becoming militarily significant. In testimony Dr. Donald Kerr, then director of the Los Alamos

[16] *Ibid.*, p. 10.

National Laboratory, stated that at the level of 150 kt positive deviations as high as 45 kt would not be significant but those as high as 150 kt would be cause for concern. Moreover, some improvements in the seismic detection system that would follow if the Threshold Test Ban Treaty were ratified could further improve the accuracy of yield estimates.

In short, there is no convincing evidence to show that the Threshold Test Ban Treaty has not been observed for the past 13 years. The uncertainty of yield estimates is within the range that is not considered militarily significant. The risk in ratifying this treaty as it stands would be minimal and the opportunities for improvement that ratification would provide are significant.[17] That additional negotiated improvements would follow is assured by the fact that such improvements would be a condition for further negotiations of a test ban.

VII

Any new test ban treaty in the context of a larger arms control effort should address several generic problems if it is to contribute to the whole and itself prove durable. It should be designed to survive inevitable difficulties and be sustainable for the long run. It seems unavoidable that the negotiations must fall into two stages: one involving the two superpowers, and perhaps the United Kingdom for historical reasons, and another to accommodate the other nuclear powers. It is reasonable that some incentives and compromises will be necessary to gain the adherence of all the nuclear countries. And a different set of incentives will be needed to attract all or nearly all of the non-nuclear countries.

Beyond this a number of technical requirements are evident: (1) The best affordable seismic technology should be used and provision made for its improvement as the state of the science matures. (2) The location of seismic stations and the transmission and processing of seismic data must meet high standards and be objectively assessed to do so. (3) Permitted testing would have to be restricted to one or two sites in each nuclear-capable country, and there should be full disclosure of the seismic characteristics of these sites together with calibration tests whose yields are certified by other than the host country. (4) The provisions for on-site inspection and other non-seismic

[17] W.H.P. Panofsky, Hearings, U.S. Senate, Committee on Foreign Relations, Jan. 12, 1987.

techniques would have to be clearly defined and the role of experts from other countries formulated. (5) How the phasing-in of the test ban would relate to progress in the other areas of strategic arms control would have to be agreed upon. (6) Procedures that would greatly improve the resolution of disputes should be a part of the new treaty. (7) The means by which a threshold is verified would need agreement, as would the problem of deciding on the lowest possible threshold. (8) Concerns over reliability of weapons would have to be met not only over the short run but for the indefinite future. (9) Agreement on a fair and acceptable means of allocating costs would be needed.

The negotiations of 1977–80 reached agreement on several of these points. The current proposal of the Soviet Union does not deal with this level of detail. However, the Soviet Union has indicated a new concern with adequate verification. On-site inspections of some type appear to be acceptable. Such provisions in the Stockholm Conference accord of 1986 are a promising beginning. Marshal Sergei Akhromeyev's pronouncements at Reykjavik on what "triple monitoring" meant in terms of verifying weapons reduction would set admirable standards if translated into the test ban context. This should mean a permanent procedure for the exchange of seismic and related data, and an acceptable structure for in-country seismic stations and their upgrading to arrays, in addition to the above requirements.

The current Soviet position on a CTB does not allow for any kind of reliability testing of weapons because the Soviets claim there will be no problem that needs to be addressed in this way. The Soviet moratorium approach, in which all testing would be stopped while verification techniques and all the other requirements are negotiated and put in place through cooperative actions, is not acceptable to the United States today as a route to agreements. Finally, the Soviet proposal does not address the question of lowest allowed nuclear explosions. On the positive side, however, credit should be given to the progress made in the CTB negotiations in the Carter Administration involving the United Kingdom, the U.S.S.R. and the United States.[18] Considerable progress was made there on verification

[18] *Nuclear Arms Control: Background and Issues*, Washington: National Academy of Sciences, 1985, pp. 199–202. Chapter 7 of this book provides useful background to many issues treated here.

procedures, the establishment of in-country networks, the provision for the international exchange of seismic data and the operation of a committee of experts. Much of this could be adopted in new negotiations.

An alternative would be to ratify the Threshold Test Ban Treaty and then to negotiate successively lower thresholds of permitted testing. If the aim is to move toward conditions that would prevent further weapons development, then lowering the threshold in phase with the detection threshold of the seismic system would be in order. This differs from the Reagan Administration approach in which the reduction in threshold would be in some way proportional to the reduction in nuclear weapons, not to verification capability. But both of these approaches are deficient. Before a step-by-step reduction of the threshold could take place, agreement would have to be reached on the verification procedures and the operational meaning of the threshold. One can predict that there would be long negotiations over each step in lowering the threshold. And each reduction of the threshold would show that each new threshold has its own set of problems. Dealing with these at each stage would be time-consuming and expensive, and would prevent coordination with the major arms control schedules that may have been negotiated.

VIII

An alternative approach can be designed that would address most of the objections raised here but still achieve the traditional goal of a CTB, that is, the halting of significant new weapons development. In formulating this approach compromises are made in the interest of producing a structure that would be attractive to both the United States and the U.S.S.R.—if they were truly committed to the traditional goal—and to other countries as well. This approach assumes that the U.S.S.R. and the United States must take the lead and demonstrate their commitment to reductions and to moving toward much smaller, safer nuclear arsenals. With at least France and the People's Republic of China uninterested in a CTB until the two superpowers have demonstrated their commitment, the United States and the U.S.S.R. would have to negotiate a first phase of a CTB to meet their own requirements. This means agreeing on a stepdown to a lower threshold which they would be willing to accept for the indefinite period that may be required to reach agreement with the other nuclear powers on a final, all-inclusive version of the CTB. Finally, this proposal makes the concession that some allowance should be made for reliability testing, but in a way that will not permit new weapons development. The basic elements, apart from many of the requirements listed above, are as follows:

First, the treaty would be initially negotiated bilaterally (between the United States and the U.S.S.R.) as Phase I, and organized in such a way as to ensure coupling to major arms reductions and to allow for subsequent negotiation with the other nuclear powers. Upon signing, the powers would begin to build a seismic network with in-country stations to monitor adequately a threshold in the range of ten kilotons. A threshold of about ten kilotons is a conservative choice, but it has two advantages. It could be readily monitored and, while it permits some testing of a class of weapons components known as primaries or triggers and some battlefield weapons, it disallows testing of most strategic weapons. One of the incentives for the other nuclear countries to negotiate and sign the complete CTB would be to close this gap in the second phase.

Phase I of the treaty should come into effect at this ten-kiloton level only when the two powers have reduced major strategic weapons by, say, ten percent and the seismic network is operating. By that time testing would be allowed only at one or two test sites and an adequate exchange of geological information would be under way. During the preceding interval—at least a year—the testing for developmental programs that are near completion, such as the warhead for small mobile ICBMs, could be finished. As reductions continued, plans for improving the seismic detection system could be implemented and the other nuclear powers could join in the negotiations of Phase II. In an optimal schedule a complete CTB could be negotiated by the time weapons reductions had reached 50 percent, in a total of five years as envisaged at Reykjavik.

Second, only if agreement was reached would the threshold be further lowered. By that time a reliable system that would monitor coupled explosions in the one-kiloton range (in hard rock) should be practical and should be tested and installed worldwide. The negotiating parties would have to decide if such a verifiable limit would eliminate militarily significant explosions. It is likely that the gap between a lowered threshold and such militarily useful tests could be eliminated, but this decision cannot be made in advance. Cavity decoupling would be forbidden. Deciding on the very low threshold, which would then become a permanent feature of the regime, would also require consideration of the false alarm problem arising from chemical explosions. In any event the range of uncertain verification would have shrunk from the present 150-kiloton level to a remarkably low level that would hardly justify evasive attempts since the military value of doing so would be negligible or nearly so.

Third, since reliability testing remains contentious and unforeseen needs may arise in the future, a provision for a very small number of tests that could not contribute to significant weapons development should be allowed. This might take the form of permitting two or three tests below a ceiling of 150 kilotons or less within a period of one day once every three or four years. By allowing only two or three tests clustered together, no significant weapons development could occur since the second or third weapon to be detonated could not be reconfigured on the basis of the outcome of the first or second test. Special verification requirements would be needed to ensure that a larger number of smaller explosions were not being carried out.

Fourth, provision would be made for establishing a committee of experts to oversee the exchange of seismic data and the operation of the seismic networks and data processing, to resolve conflicting views of data and of interpretation of the treaty, and to recommend procedures for the prompt resolution of conflicts that it cannot settle.

The scope of this alternative is broad and its enactment would take years. This contrasts sharply with the view sometimes expressed in both the Soviet Union and the United States that the negotiations of a CTB could be completed in a few months. But under present conditions, a treaty quickly arrived at and standing alone would not likely survive the political strains that would engulf it. The lower threshold would invite far more claims of violation than we have seen up to now. The profound change in the nuclear testing pattern required to end further development of nuclear weapons worldwide is a heroic undertaking; it requires a commitment to move decisively on the comprehensive control of nuclear weapons. Such commitment can only come from the realization that a new regime of nuclear weapons reduction and control is more desirable than continuing the present qualitative arms race at high cost and unnecessary risk.

The present development of nuclear weapons is sufficiently advanced to provide all that is needed to maintain nuclear deterrence for as long as necessary. Within such a framework, a test ban treaty that has the character of a caretaker regime would ensure the reliability of the deterrent without further weapons development, and at minimal risk and cost. A test ban of the kind described, modified as political reality may require, can play an essential role in such a new arms control regime. Since the last attempt to negotiate a CTB treaty ended in 1980, seismology has improved, weapons development has matured still further, more near-nuclear countries are edging toward a decision to go nuclear, and the United States, the Soviet Union and their allies support a broad movement toward a nuclear balance at successively lower levels and greater stability. The conditions are ripe and the need is evident for another try.