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A Comprehensive Ban on Nuclear Testing

Robert Neild and J. P. Ruina

The technical, strategic, and political aspects of a comprehensive test ban (CTB) treaty have changed since they were debated in the negotiations leading up to the limited test ban (LTB) treaty of 1963. Progress in the technical art of seismic monitoring may now permit nations to overcome the verification obstacle that blocked the CTB in the past. The gradual realization that new nuclear bomb technology is not critical to the strategic balance between the superpowers has also reduced concern about the risks of entering into a CTB.

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In this article, we review the range of issues involved in the consideration of a CTB. Often the negotiaions at Geneva and the internal debates in the United States have been so dominated by technical issues, notably those regarding verification, that the political and military significance of a CTB has been lost or ignored.

Background

Any history of the LTB must consider the dimensions of the process of negotiations. The most obvious dimension is the record of official statements and the formal negotiating process itself—that process in which the parties to the negotiations make evident their policy decisions regarding negotiations. Much of the written history of this dimension is available (*1*). However, what is less evident is the nature of the intragovernmental negotiations that necessarily precede and accompany intergovernmental negotiations. We know a good deal about the United States' internal process. We know almost nothing about the Soviet Union's, but we must assume nevertheless that, in that country too, there was internal argument and debate on the test ban issue. The international negotiations consisted largely of sparring rounds on a few issues—the test ban's relation to more general disarmament and on-site verification. What we know about the internal debate in the United States and what we surmise about debate in the Soviet Union point up political and military issues that were never stated in the international negotiating process, but that were, nevertheless, motivating forces behind each country's position.

A test ban was proposed in 1954 after both the United States and the Soviet Union had tested thermonuclear devices and after the fallout from a particularly large U.S. test (15 megatons) in February 1954 had affected the crew of a Japanese fishing boat. From then until 1963, when the LTB treaty was signed, there were periods of serious negotiations, periods devoted to technical analyses, and a test ces-

sation lasting almost 3 years—during which each side agreed to refrain from testing if the other did likewise—often punctuated by unilateral proclamations or bitter accusations, or both.

The United States was worried that a nuclear test ban would be a prelude to a ban on the use and even the possession of nuclear weapons and that this would eliminate the West's nuclear superiority, which was considered necessary to balance Soviet superiority in conventional forces in Europe. A test ban was therefore held to be detrimental to the West unless limitations on nuclear forces were tied to limitations on conventional forces. In 1959, the United States dropped its requirement that the test ban be linked to other disarmament measures. It focused its "anxieties" on the technical questions involved in verification. American technical analyses indicated that monitoring nuclear explosions would be particularly difficult if the tests were underground. As a consequence, the United States insisted that, before it would sign a comprehensive test ban treaty, it must have the right of on-site inspection. The Soviets, for their part, viewed this U.S. requirement very suspiciously and claimed that this was required not for technical reasons, but for the U.S. intelligence services. However, for a short time in the course of the negotiations, the Soviet Union took the significant step of agreeing to permit a certain small number of on-site inspections. Considering previous Soviet attitudes toward any foreign intrusion, this appears to have reflected great interest on their part in reaching an agreement at that time.

When resolving the Cuban missile crisis in 1962, both powers recognized the need for détente and a demonstration of reconciliation. A nuclear test ban treaty, which was ripe for conclusion after years of negotiation, was mentioned in this connection in the exchange of messages during the crisis. In renewed negotiations, the Soviet Union revived its willingness to accept a small number (that is, two or three) of on-site inspections per year. For its part, the United States reduced the requirement from between 12 and 20 inspections per year to seven per year. An agreement seemed virtually in hand. However, existing doubts and internal pressures found expression in arguments about the exact number of on-site inspections required. A compromise between three and seven was not reached. In retrospect, it is difficult to see how U.S. security could have been dependent on precisely seven on-site inspections or how Soviet security could have been more compromised by seven (or five) inspections per year than by three. But this numbers game became a politically insuperable obstacle to an agreement that banned underground testing. Fortunately, the leaders of both sides salvaged some of the spirit of the negotiations and agreed to the LTB. On 10 October 1963, the LTB, with no prohibition on underground testing, came into force. It included a commitment to continue negotiations for a CTB.

The Soviet Union later withdrew its offer permitting on-site inspections. Looking back, we can see that not only was the opportunity to reach a CTB agreement missed, but also, and perhaps more important, the opportunity to introduce reciprocal on-site inspections in the Soviet Union and the United States was missed. If the precedent of on-site inspections had been established, subsequent disarmament negotiations might have been more fruitful.

The internal debate in the United States was much less about on-site inspection per se than about the ease with which the Soviet Union could secretly violate a test ban agreement. Those who were particularly suspicious of the Soviet Union believed it folly to agree to anything that limited U.S. freedom to test. Looking back at the late 1950's and early 1960's, we can see that ambiguous positions, vacillation, and slow decision-making reflected internal differences over the general wisdom of a treaty, as well as over specific aspects of a treaty, such as the danger of fallout and the military necessity for underground tests.

When, after the Cuban crisis, President Kennedy determined that a treaty was important, he was willing and able to resolve some of the internal differences; thus the LTB resulted. We know from public statements and from the changes in the Soviet Union's position that they, too, had some internal problems. Khrushchev later recounted his struggle to persuade his Council of Ministers to agree to three on-site inspections when he felt that the United States would accept this too (*2*).

Before the LTB went into effect, the United States and the Soviet Union were almost totally preoccupied with the issues as they affected their relationship to each other. Other countries, by and large, took positions that can be explained in part by their places in the nuclear hierarchy. Britain generally seemed to want to eliminate the political and technical obstacles that arose, but, until the completion of its weapons test series in 1958, Britain was less positive about immediate cessation of tests. France felt that its position demanded that it pursue the development of nuclear weapons unless there was going to be complete nuclear disarmament; France started its testing program in 1960, during the U.S.-Soviet testing moratorium. China likewise advocated full nuclear disarmament. However, in July 1963, when the LTB was being concluded, China publicly denounced the agreement. This seems to have been a major step in the breach in Sino-Soviet relations. The LTB was negotiated without the participation of China and France, and this no doubt added to their annoyance. The remaining countries were generally without nuclear weapons and without nuclear ambitions, and they supported a test ban as a way to prevent nuclear fallout and as a door to arms limitation.

Since the LTB, nuclear testing by the superpowers has not ceased, but has gone underground. The total number of tests reported by U.S. authorities before and since the LTB, as of 1 January 1971, are United States, 539 (310 before, 229 since); Soviet Union, 173 (126 before, 47 since); Britain, 25 (23 before, 2 since); France, 37 (7 before, 30 since); and China, 11 (all after the LTB). Swedish Defence Research Establishment figures indicate Soviet tests to be 236 (163 before, 73 since). There are indications that the actual number of U.S. and Soviet tests may be substantially higher than the numbers officially announced.

Verification

For over a decade, the presumed obstacle to a CTB was whether or not national means of verification were sufficient to monitor tests and verify that a CTB was not being violated. Specifically, the question centered on whether on-site inspections were necessary to verify compliance with a treaty.

The U.S. position has been that the main means of monitoring underground nuclear explosions is analysis of seismic signals. This involves two

steps—*detection* (that is, a signal must be detected, thus indicating that there has been a seismic event and, as far as possible, locating it) and *identification* (that is, analyzing seismic signals generated by the event to see whether the source was an explosion or an earthquake). Not all detected signals can be identified (*3*). Therefore some on-site inspections were demanded as a means of spot-checking that detected but unidentified signals were not caused by nuclear explosions. The United States has always been prepared with a mass of technical evidence to support its position that seismic identification without on-site inspection was an inadequate means of verification.

The Soviet Union has engaged in technical discussion but has not linked its technical arguments directly to its position that on-site inspection is not necessary for verification.

Since it was recognized that only seismic evidence could be used to demand an on-site inspection, this form of verificaiton was limited to tests that could be detected by seismic means. This seems to indicate that the United States was willing to risk possible Soviet treaty violations stemming from both very low yield tests and from intermediate yield tests that, in theory, could be seismically concealed, but was unwilling to risk possible violations from seismically detectable tests.

At the time of the signing of the LTB, the United States estimated (*3*) that:

1) A seismic detection system could be built, with instruments placed outside the Soviet Union, which would have a high probability of detecting underground tests of about 1 to 2 kilotons in hard rock, as well as earthquakes giving comparable signals. Underground tests in softer materials such as dry alluvium generate signals that are smaller by as much as a factor of 10 and therefore would have to be 10 to 20 kilotons in yield before being detectable.

2) Such a system would detect about 170 earthquakes annually in the Soviet Union. Of these, only about 20 would be clearly identifiable as earthquakes by seismic techniques then in hand.

3) Concealment methods, such as muffling seismic signals by testing in very large cavities or masking signals by making tests coincide with earthquakes, could, in principle, make it possible to test at much higher yields —perhaps up to 100 kilotons—without seismic detection. Such concealment methods were costly and fraught with practical engineering difficulties, but they might be feasible on some scale. They would also increase the likelihood of detection by nonseismic means.

Since the LTB has been in effect, progress in seismology has demonstrated that the detection threshold can be somewhat lower than the level of 1- to 2-kiloton explosions in hard rock. Of far greater importance is the discovery that explosions almost always produce smaller long-period surface waves than do shallow focus earthquakes of the same body wave magnitude. This means that, if desired, systems can be built which can identify explosions and earthquakes extremely well, down to a level equivalent to about a 5-kiloton explosion in hard rock, leaving only a small number of detected but unidentified events annually (*4*). Moreover, improvements in identification give promise of continuing down to levels equivalent to 1- to 2-kiloton explosions in hard rock, although it will never be possible to identify all seismic events that are detected, since identification requires more information than detection (*5*). To go further in improving seismic means for monitoring underground explosions, it would be necessary to lower the detection threshold, which will become ever more difficult. Thus, the point of diminishing returns for seismology research in nuclear test monitoring may soon be reached. Meanwhile, the systems installed and now operating lag some way behind the technical possibilities described here.

The problems of concealment are pretty much the same as they were. Any analysis of the significance of concealment must take account of the fact that making progress in nuclear weapons technology poses serious practical difficulties and that these are compounded by the requirements of clandestine testing. What is often forgotten is that the primary goal of a nuclear testing program is advancing nuclear weapons technology—not avoiding detection per se. Clandestine testing is not predominantly a game of "hide and seek." No country is going to embark on necessarily costly, complicated, and risky concealment measures unless it judges the gains to be great.

In addition to the progress in seismology, research carried on in the United States on the technical aspects of on-site inspection has shown that visual observation and radiochemical analysis are the only useful techniques, but that even these techniques are not effective when a test explosion is sufficiently deep to prevent surface disturbances and seepage of radioactive gases to the surface (*6*).

The improvements in seismic detection reduce substantially the need for on-site inspection. The now manifest technical limits to the effectiveness of on-site inspection further reduce its significance both as a means of verification and as a deterrent to treaty violations.

However, interest in on-site inspection has not disappeared, since the door to possible violation with tests above the seismic detection threshold cannot be completely closed by seismology. Every method, including on-site inspection, that offered any hope of aiding verification and increasing the difficulties and risks for a potential violator would be grasped, if great military importance were to be attached to the occasional tests that might be detected, but not identified, seismically.

Recognized but rarely discussed are nonseismic means for detecting and identifying underground explosions. Satellite sensors can be exploited for this purpose, as can traditional means of intelligence, although how helpful either of these methods is in supplementing the seismic means is not known to the public. They can be helpful in detecting clandestine tests and in directing careful examination of seismic records relating to specific times and locations. They may also be significant in helping to identify suspicious events first detected seismically.

The significance of nonseismic means is that they are varied and secret and that they may not diminish in effectiveness with smaller tests in the same way as seismic means. It will be hard to find ways to deceive them all, and a potential violator will not feel secure, no matter how much effort he puts into seismic evasion.

Although the need for on-site inspections was a key issue to both the United States and the Soviet Union, the character and details of on-site inspections were but little discussed. How intrusive need they be? How well would they work? The lack of discussion of these issues may indicate that neither nation expected to be allowed an on-site inspection at a real test site,

and that, at most, they regarded the right of on-site inspection as only a deterrent to cheating. But it may also be that on-site inspection was mainly a proxy issue for other apprehensions that the superpowers had about signing a treaty or for their inability to have their disparate constituencies face up to accepting a treaty. Now on-site inspection seems hardly relevant to the important considerations involved in assessing the risks and benefits of a CTB.

There are very few references to the problems of verification for countries other than the superpowers. This is so for a combination of reasons.

1) The superpowers are no doubt interested in observing the military activities of other countries, including, in particular, the testing of nuclear weapons and their delivery systems. But if they observe tests by Britain, China, France, or any other country that "goes nuclear," this is not likely to influence strongly their own highly advanced programs for testing nuclear warheads.

2) The acquisition of nuclear weapons has been an overt act from which governments sought to derive political advantage. Most countries would not go nuclear by clandestine testing.

3) Countries going nuclear are likely to start with tests large enough to detect. To date, such tests have usually been around 20 kilotons. For technical reasons, this appears to be the easiest and the most economical size for a first weapon.

It is important to note that there are great variations in the technical difficulty of monitoring different countries. Israel, a very small and barren country, should be very easy to monitor; Japan, large and highly seismic, relatively hard to monitor. Also, the great variation in political openness of different countries allows very different levels of collateral intelligence to be obtained about nuclear developments.

Military Significance of Tests

The next question to consider is the nature of the military attractions to the two superpowers of continuing nuclear tests and, in particular, what, if anything, could be gained by illicitly conducting nuclear tests after a CTB was introduced.

Nuclear tests are conducted to maintain confidence in existing stockpiles, to prove the feasibility of new weapons designs, to measure nuclear explosion effects, or to contribute to research and development in weapons technology. Some tests serve more than one purpose.

Confidence tests are occasional tests for the purpose of maintaining confidence in weapons already stockpiled. Since materials age and inadvertent changes may occur in production, military authorities frequently insist on sampling the performance of their weapons. These tests are not intended to advance the state of the art.

It is not clear that such tests are really needed, since a bomb need not have any moving parts and tests of the entire device, short of going nuclear, can be carried out. Nuclear fuels work, as the world knows all too well, and their chemical integrity can be checked by conventional chemical means. If all tests were prohibited, steps would surely be taken to minimize the possible deterioration in the reliability of the weapons. Bomb designs, material standards, production methods, and so on would be rigidly frozen. But to the extent that confidence diminishes, it is more likely to affect the attitude of those who plan a first use than of those who plan retaliation only. The effect, if any, is to widen the firebreak between nonnuclear and nuclear weapons and to shift nuclear weapons gradually toward the role of weapons that are useful only to deter nuclear attack.

Proof tests are tests of newly designed weapons whose designs are based on accepted and established principles. New designs are needed to meet size, weight, shape, or other performance requirements. Before stockpiling, it is necessary to test a new weapon to see whether it works as intended and expected.

Tests without nuclear explosives or at less than full yield will give less than full confidence. Occasional single tests can do the job; but full diagnostic instrumentation, which raises the risk of detection by nonseismic means, is not necessary, although useful in the event of failure.

Without proof tests it would probably be necessary to design new weapons systems around existing nuclear bomb designs (*7*). The effect is different for weapons intended to deter attack than it is for those intended to enhance the capability for fighting wars.

For the purpose of maintaining a credible deterrent, the case for continued upgrading and redesign of nuclear weapons is hardly persuasive for several reasons: (i) deterrent weapons tend to be in the larger yield class, in which warheads of high efficiency are already available to both superpowers; (ii) several different bomb designs can be used to make up a deterrent force, thus minimizing the possibility of a catastrophic failure in the force's retaliatory capability; (iii) so much overkill already exists that greater efficiency in the nuclear arsenals of either power is hardly needed for deterrent capability.

It is interesting in this regard to speculate on whether or not the deterrent capability of either power would have suffered if a CTB had been in effect for the last decade. For example, in the development of MIRV's (multiple, independently targetable reentry vehicles), the most significant advance in long-range nuclear weapons in the past decade, it is safe to assume that a system could have been made using warheads of existing design and that testing has merely permitted a better combination of the numbers and sizes of warheads for a given missile.

Another argument for the need to continue testing is that it may lead to the design of a new and effective defensive system that would be critical to the strategic balance. But for the superpowers, improvements in warheads are not likely to be as important as developments in other parts of the present defensive systems. This can be seen in the fact that, in many U.S. debates about technical limitations of the ABM (antiballistic missile), the limits imposed by nuclear technology are not mentioned—all the emphasis is on the deficiencies of radar, computers, component reliability, and so on (*8*).

For military systems intended for fighting wars, the case for continued upgrading of nuclear weapons is stronger, but is still not compelling. Since these systems are designed to battle with an adversary's system, superior performance makes military sense. Technical improvements in nuclear warhead design can make for superior weapons systems. However, other technical aspects of the system (for example, speed, agility, and range), in addition to such factors as military tactics and troop training, will generally be more important to the performance of the system than the precise character of the nuclear bomb it delivers. Moreover, it can be argued that the superpowers, with their long history of intensive research and development and with their many tests,

already have so complete an arsenal of weapons designs that a suitable, though probably not optimal, design can be found to fit almost any particular requirement.

In effects tests, nuclear explosions are used to provide a realistic nuclear environment in which to test materials, electronic devices, the survival of weapons against defense measures, and so on.

Tests of this kind are now conducted underground and are primarily for the purpose of improving designs of warheads for ABM interceptors and for missiles intended to penetrate ABM defenses. By now, the superpowers have had so much experience with underground tests that they could pursue a serious (though limited) program of effects tests even if they were restricted to yields below the seismic detection threshold. With time for even more testing and with growing disillusionment about the military utility of ABM's, the need for effects tests should become less compelling. An international limitation of ABM's, if stringent, would certainly reduce the argument for effects tests.

Some effects tests are ruled out now by the LTB's prohibition on atmospheric testing. For example, existing missile silos appear not to have been subjected to air-induced ground shock from nuclear explosions by either superpower; nor has the phenomenon of radar blackout, induced by nuclear explosions, been fully explored experimentally.

Research and development tests, including tests to investigate entirely new principles in weapons design, would be needed to advance the state of the art toward pure fusion bombs, neutron bombs, or major advances in yield-to-weight ratios for very small weapons. Large weapons are already very close to their theoretical maximum in yield-to-weight ratios, and improvement by a factor of 2 is probably all that we can reasonably expect. This is quite insignificant compared with the advances made to date; for example, the yield of current weapons per unit of weight is about 1000 times greater than that of the bomb dropped on Hiroshima (*7*).

Vigorous research and development appears to be continuing on the assumption that a breakthrough, comparable in significance to the original development of the A-bomb and the H-bomb, may lie around the next scientific corner. Before the LTB, advocates of the importance of nuclear research and development to military security came up with the possibility of a "clean" bomb, which would minimize radioactive fallout, for strategic use, and a "neutron" bomb, which would reduce blast effects but maximize lethal neutron radiation, for tactical use. Neither of these potential weapons now seems significant in the military equation, and the advocates of tests have not come up with anything "exciting" since then—perhaps because the test ban issue has been quiescent. But of course it is impossible to prove that something of significance will *not* be invented. Fears of the undiscovered will undoubtedly persist, although they lose a great deal of their strength as time passes and nothing spectacular emerges from research programs. It is now about two decades since the H-bomb was developed. Progress has not stopped, but research and development in nuclear bomb technology seems, as might have been expected, to be yielding diminishing returns. Much of the technical cream was skimmed in the first decade after the A-bomb was developed.

Research and development in nuclear weapons technology can continue without nuclear testing, but, of course, with a very reduced scope.

In the light of considerations like these, it is a matter of judgment as to how highly one should value, in military-cum-political terms, the results now derived by the superpowers from nuclear tests. It seems clear that the results are not as important as the results of the first tests undertaken by these or any other nations. Both the military and political returns may now be low. If they are low, the benefit of a CTB as a direct step to stop the arms race between the two superpowers is low, but so are the obstacles to achieving that step. If the returns are high, the benefits are high and so will be the obstacles—in terms of the arguments about what the other side might gain if it tested clandestinely. In either case, those who work in the nuclear weapons and test programs will press for continued tests.

While there are no particular grounds for assuming that if either superpower chose to break a CTB it would do so secretly rather than openly, it is interesting to speculate about the conceivable character of a clandestine test program. If one assumes that a violator would risk nonseismic detection, but not seismic detection and identification—an assumption for which there is no strong foundation—then small tests will be safer than big ones. A clandestine program might, in such a case, include a series of underground tests in soft, dry material to muffle the seismic signal, in carefully chosen locations and at a fraction of a kiloton, and perhaps occasional tests in the 20- to 80-kiloton range once every year or two, perhaps in the shadow of an earthquake.

A program of this kind would permit continued research and development and the measurement of effects to be carried further than would be possible with no tests, but probably not as far as is possible now with unlimited underground testing.

On the other hand, it would not be possible to have proof or confidence tests of very large warheads. Also, except for warheads of small yield, it would not be possible to develop warheads fully by using new technology, since such development would probably require many tests.

This suggests that, as far as the superpowers with their huge armories of nuclear weapons are concerned, the testing and development of small nuclear weapons could scarcely be expected to change the balance of power. The military in the superpowers might show an interest in improving those small weapons that they believe might improve their ability to fight nuclear wars short of a major nuclear exchange involving their homelands; however, it is questionable whether the notion of a limited nuclear war is realistic, let alone desirable.

It can be argued that the nation that had continued small tests would be able to keep its nuclear weapon design teams together and to maintain the vigor of its weapons laboratories. In this way, it would have a lead over a nation that had not continued testing, if and when a treaty was not renewed or was abrogated. The substance of this argument rests on the highly questionable premise that a lead of this kind could give one superpower a significant political and military advantage over the other, even though each of them already has such a vast and variegated arsenal of nuclear weapons.

For China, France, and the United Kingdom, however, the situation may be very different. These countries do not possess the variety of nuclear

weapons that the superpowers possess. The state of nuclear technology in France and China is considerably behind that of the superpowers. The point of diminishing returns has certainly not been reached in efforts to provide more variety for their arsenals and in improving weapons. Although to be in the same "nuclear class" as the superpowers would mean building up the quality and quantity of delivery vehicles, which presents more serious obstacles than progressing in nuclear technology, these countries would be substantially limited in their ultimate capability if they stopped nuclear testing now.

The interest and need for testing may be different for each of the nonnuclear powers. Some could probably develop and store a small nuclear arsenal without any nuclear tests. With knowledge about fission weapons now available to anyone, it is feasible to design simple weapons and be confident that they will work, even if they are not tested. Most of the fundamental design work and essential laboratory tests can be carried out without having any nuclear explosions. However, if the desire were to stockpile weapons of a more advanced design without any nuclear tests, it could only be at the cost of diminished confidence in such weapons.

Peaceful Nuclear Explosions

Possible peaceful uses of nuclear explosives were first explored in the United States as Project Plowshare. Applications investigated include earth moving and excavation, natural gas and mineral extraction, extraction of geothermal energy, creation of underground storage areas, and so on. The enthusiasm of U.S. scientists for peaceful applications of nuclear explosives stimulated interest in exploiting this technology elsewhere in the world. But in recent years, U.S. enthusiasm for peaceful nuclear explosions has diminished. Preliminary experiments and detailed analyses now suggest that the potential of nuclear explosions for peaceful purposes is limited and that often other methods can be found for accomplishing the same things.

Contributing to the disillusionment with peaceful applications of nuclear explosions is the realization that full exploitation of nuclear explosions for each feasible application would require very large numbers of explosions. For example, it may take hundreds of nuclear explosions to extract significant amounts of gas or other minerals. If several countries were to exploit nuclear explosions for such purposes, thousands of explosions would occur. This might again raise concerns about radioactive contamination.

But the major question here is whether it would be possible to separate civilian from military nuclear explosions and hence whether it would be possible to prohibit military explosions in a CTB while permitting peaceful explosions.

It may be that verification procedures could be devised to ascertain that no military purposes were being served in a particular program of nuclear explosions—that is, that the peaceful explosion was not also serving the purpose of a proof or confidence test or that new bomb technology was not being tested in peaceful applications. Even if such procedures could be devised, they would undoubtedly involve some detailed disclosures about the explosive device to all participants—nuclear and nonnuclear—and thereby work counter to the purposes of the nonproliferation treaty. They would also involve observation by foreign technicians, sampling and analyses of the products of the explosion, and so on. All of these means of verification could be considered intrusive and would probably be difficult to negotiate. On the other hand, without verification, peaceful nuclear explosions make violation so easy that any country might eventually succumb to exploiting a peaceful program for some military purposes.

From what we now know, the benefits from a program of peaceful explosions hardly seem to match the costs, particularly if the costs include ruling out a CTB. But a CTB need not rule out possible peaceful applications forever. One approach would be to ban all nuclear explosions initially, stipulating that for a period of several years parties to the agreement should jointly investigate methods of verifying that military applications are not being pursued in a program of peaceful nuclear explosions. If further analyses suggest that peaceful explosions are more promising than they now seem, the incentive to exploit them constructively while having a ban on military tests might encourage unprecedented international cooperation.

Conclusions

Our foregoing analysis of the role of a comprehensive test ban leads us to the following conclusions.

1) A CTB by itself will have little direct effect on the arms race between the superpowers. It would not hinder their nuclear arms production and deployment nor would it necessarily present a significant obstacle to the development of new nuclear weapons systems, despite limiting the development of new nuclear warhead designs. It can hardly make a dent in the destructive capability of the superpowers or in their ability to step up the pace of the arms race.

2) The chief merits of a CTB reside in the political sphere. It would help promote détente and could help to escalate interest in arms control agreements of broader scope. But in neither of these effects would it be as significant as a successful SALT (strategic arms limitation talks) agreement. The CTB also lingers as a piece of *unfinished business* since the signing of the LTB in 1963. The question can be and has been raised, "If the superpowers are serious about arms control, why have they not accepted the CTB, which is simple in concept and in form and is also free of serious military risks?" Such doubts about the sincerity of the superpowers' willingness to limit their own arms development will persist as long as there is no CTB. Substantial agreement at SALT would lessen some of this effect too, but would not eliminate it completely.

3) Recent progress in seismic identification has been impressive, and other means of obtaining technical intelligence about nuclear testing have probably also improved greatly. In addition, research on the technical means of on-site inspection has demonstrated its limited effectiveness. Therefore, the role of on-site inspections as an added deterrent to cheating on a CTB has diminished substantially. This is not to say that detection and identification of all nuclear tests is possible now, or ever, but only that on-site inspection would add very little to the other technical means now available for verification.

4) It will become increasingly difficult in the United States to oppose the CTB on the basis of risks that accompany possible Soviet evasion of a treaty that does not include the right of on-site inspection. The opposition to a

CTB is now likely to shift to the more direct argument that nuclear testing is important to keep pace with continuing worldwide technical and military developments. The justification for U.S. testing is only in part because of advances in Soviet nuclear technology per se. Those opposing a CTB may argue that it makes little sense, and may even be courting danger, to freeze nuclear technology alone and that banning nuclear tests should await an agreement that copes with all military research and development and all qualitative improvements in weapons systems. This directly confronts the argument that the unique virtue of a CTB is that it provides a simple and feasible first step in the very complicated problems of controlling military technology.

5) The mutual deterrence of the superpowers will not be compromised if a CTB agreement is reached and one side or the other clandestinely violates such an agreement. The state of nuclear technology in both countries is mature, and the destructive capability of their nuclear arsenals can be easily maintained. Whatever small improvements can come as a consequence of clandestine testing would hardly affect the strategic balance.

6) It seems unlikely that China and France will agree to stop testing in the near future. These countries refused to join the nonproliferation treaty, which did not affect their nuclear programs, and it is doubtful that, proceeding from military considerations alone, they would join a CTB. Their nuclear programs are still not mature, and a CTB would freeze their positions of inferiority with respect to the superpowers. There may, however, be wider political and security arrangements to induce them to participate. Cessation of tests by the other nuclear powers might serve as an inducement to China and France to refrain from testing.

7) The key near-nuclear powers, such as Japan, India, and Israel, are much more concerned with the military activities of their neighbors than they are with those of the superpowers. The modest nuclear restraints that a CTB imposes on the superpowers are hardly likely to have a direct impact on the approach of these countries to their own security. However, for these critical near-nuclear countries a CTB may be much more acceptable than the nonproliferation treaty. A CTB would not prohibit the production of fissionable material, the development of nuclear weapons technology short of testing, nor the stockpiling of untested nuclear weapons, and is therefore less restrictive. Consequently, these powers may be willing to ratify a CTB, but not the nonproliferation treaty. On the other hand, the CTB may provide them with a ready excuse for not succumbing to the pressure to ratify the nonproliferation treaty, if indeed they need excuses or would bow to such pressure.

8) A CTB is of very little added, direct significance to other nonnuclear powers who have already ratified or are about to ratify the nonproliferation treaty. It may only lessen their pique about the treaty's being highly discriminatory—the treaty imposes no restraints on the nuclear weapons programs of the nuclear powers, while the CTB restricts all parties to the agreement.

9) Peaceful nuclear explosions do not now show great promise and significance for economic development. What can be done with peaceful explosions can often be done by other means, although possibly at a slightly higher cost. On the other hand, making allowance for peaceful explosions greatly complicates a CTB. A useful approach to the problem of banning military tests but not foregoing indefinitely the use of peaceful explosions might, therefore, be to ban all nuclear explosions for a period of several years and to stipulate in the agreement that in that time there would be negotiations on how peaceful explosions may be controlled in a way that would not jeopardize the CTB.

References and Notes

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2. N. Cousins, *Sat. Rev.* (7 November 1964), pp. 16–21, 58–61.
3. U.S. Congress, Joint Committee on Atomic Energy, *Hearings on Developments in Technical Capabilities for Detecting and Identifying Nuclear Weapons Tests* (88th Congr., 1st sess., 1963).
4. See the working paper (Conference of the Committee on Disarmament, document No. 330, 30 June 1971) at Geneva by S. Lukasik, director of the Advanced Research Projects Agency. This paper was also introduced in the record of U.S. Senate, Foreign Relations Subcommittee on Disarmament, *Hearings on the Comprehensive Test Ban* (92nd Congr., 1st sess., 1971), pp. 111–115; J. F. Evernden, W. J. Best, P. W. Pomeroy, T. V. McEvilly, J. M. Savino, L. R. Sykes, *J. Geophys. Res.* **73** (No. 32) 8042 (1971).
5. See testimony of J. Brune (*4*, pp. 139–149).
6. See testimony of S. Lukasik, U.S. Congress, Joint Committee on Atomic Energy, 27 October 1971, in press.
7. J. C. Merk, in *The Impact of New Technologies on the Arms Race,* B. T. Feld T. Greenwood, G. W. Rathiens, S. Weinberg, Eds. (M.I.T. Press, Cambridge, Mass., 1971), pp. 133–139.
8. See U.S. Senate, Committee on Foreign Relations, "Strategic and foreign policy implications of ABM system," *Hearings before the Subcommittee on Internal Organization and Disarmament Affairs of the Committee on Foreign Relations* (91st Congr., 1st sess., 1969).