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A STAFF REPORT

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PREFACE

On July 22 and 23, 1971, the Arms Control Subcommittee held hearings on current prospects for a comprehensive test ban agreement. As chairman of the Subcommittee, I asked the Foreign Relations Committee staff to study the record of these hearings and to prepare a brief report reviewing the main issues discussed by the various witnesses. The staff study which follows is a very useful summary which I hope will be helpful to the Congress and general public. The issues are complex—but important to understand if we are to move toward the negotiation of a comprehensive test ban.

I would like to thank the staff of the Foreign Relations Committee, particularly Mr. Phillip R. Trimble who assists the Arms Control Subcommittee, for their contributions to this report.

EDMUND S. MUSKIE,
Chairman, Subcommittee on Arms Control,
International Law and Organization.

INTRODUCTION

Since the signing of the Limited Test Ban Treaty in 1963—one of the most significant arms control measures of the nuclear age—the world has been spared the consequences of nuclear testing in the atmosphere by the United States, the United Kingdom and the Soviet Union. While continued testing by France and China—countries which did not sign the Treaty—has stimulated vigorous objections by many governments, nuclear testing virtually disappeared as a public issue following the Limited Test Ban. Meanwhile, the rate of nuclear testing actually increased and the arms race continued its own momentum, only marginally restrained by the inconvenience posed by having to conduct nuclear tests underground.

Recently the subject of nuclear testing has returned to the arena of public discussion. The multimegaton tests by the United States in Alaska and the U.S.S.R. in the Arctic have recalled attention to this subject and to the lack of progress since 1963 toward a comprehensive test ban (CTB) covering underground tests as well. The question has been raised with increasing frequency—what are the barriers to a ban on *all* nuclear tests? The hopes and expectations generated by the Limited Test Ban Treaty, when it seemed that we were so close to a total ban, have remained unfulfilled.

The possibilities of movement toward a CTB have always foundered on the question of on-site inspection. In 1963 the dispute focused on the *number* of permissible inspections (although there were other unresolved issues involving on-site inspection). The United States insisted on seven such inspections, while the U.S.S.R. would accept only three. Subsequently the Soviets took the position that on-site inspection was no longer necessary and that national means of verification were sufficient. In contrast, the U.S. position has remained unchanged since 1963.

In that period, however, enormous advances have been made in seismology so that it is now possible, through seismic means alone, to identify underground explosions to a degree unknown five years ago. It is now possible to deploy a new seismic monitoring network which would constitute a powerful force in the monitoring of a CTB. In addition, even presently deployed systems are vastly superior to those deployed a few years ago. These advances would seem to justify, indeed require, a reassessment of the U.S. position regarding on-site inspection. Yet there is little evidence that the United States is preparing any initiative in this area. In fact, funding for seismic programs since 1969 has been diminishing, not increasing, a trend which does not suggest a high priority for further progress in this area.

Many of the nations at the Conference of the Committee on Disarmament in Geneva are becoming increasingly impatient with the lack of progress toward a CTB and the lack of precise proposals or serious negotiations on the part of the nuclear powers. They raise the difficult question of whether the nuclear powers are taking the further steps toward disarmament which were promised the non-nuclear powers upon the signing of the Non-Proliferation Treaty. The lack of progress toward a CTB has become the focal point of attention, and the continued U.S. insistence on on-site inspection is viewed by many of those nations as an untenable position in light of seismic improvements. Most recently Canada has parted company with the United States on this issue, calling for the United States to make a determined effort to eliminate the "political difficulties" caused by its insistence on on-site inspection.

The issues involved are extraordinarily complex. The following is an analysis based on material developed in public hearings before the Subcommittee on Arms Control, International Law and Organization held on July 22 and 23, 1971. This Report may serve as a basis for further discussion of the obstacles to a comprehensive test ban and to a reassessment of the possibility of an initiative in this area, including the significance of on-site inspection as an element in the U.S. negotiating position.

Participants in the Hearings

On July 22 Mr. Philip J. Farley, Acting Director of the Arms Control and Disarmament Agency (ACDA), set forth the Administration's position with respect to a CTB. On that day the Subcommittee also heard testimony from Dr. Franklin A. Long, who was Assistant Director of ACDA for Science and Technology during the period when the Limited Test Ban Treaty was concluded. Now a professor of Chemistry and Director of the Program on Science, Technology and Society at Cornell University, Dr. Long testified as to the relative risks and benefits of a CTB for the United States. On the same day, Dr. Bernard T. Feld, Professor of Physics at MIT and President of the Council for a Livable World, appeared on behalf of the Task Force for the Nuclear Test Ban and discussed the effects of a CTB on the nuclear arms competition in the non-nuclear world.

On July 23, the Subcommittee heard testimony from Senator Mike Gravel of Alaska and Mr. John Havelock, the Attorney General of Alaska, regarding the Cannikin nuclear test on Amchitka, from Dr. Carl Walske, Assistant to the Secretary of Defense for Atomic Energy, on the military effects of a CTB, and from Dr. James N. Brune, Professor of Geophysics at the Institute of Geophysics and Planetary Physics and Scripps Institution of Oceanography at the University of California, San Diego, as to the current status of seismic means of identifying earthquakes and explosions.

Policy Considerations Supporting a CTB

The United States has pledged, under the Limited Test Ban Treaty, to seek to achieve "the discontinuance of all test explosions of nuclear weapons for all time." This commitment was recalled in the 1968 Non-Proliferation Treaty (NPT) and provision was made

for a conference in 1973 which will, among other things, review the progress made toward that end.

As indicated by many of the witnesses testifying before the Subcommittee, including Philip J. Farley, Acting Director of ACDA, speaking for the executive branch, the principal benefits to be derived from an effective comprehensive nuclear test ban include the following: First, a CTB would render significantly more difficult the development of nuclear weapons by those signatories which do not yet have them, and it would reinforce the Non-Proliferation Treaty by encouraging adherence to that Treaty by the countries which have not already done so. The purposes of the NPT are an important foreign policy objective of the United States which should not become obscured with the passage of time and the direction of attention to more pressing matters. As Franklin A. Long stated before the Subcommittee:

> It is reasonable to suppose that the longer the U.S. and the U.S.S.R. postpone active negotiations [on a CTB], the more discouraged the currently non-nuclear nations will become and the more likely it is that they will make a decision to develop their own nuclear weapons. And a world of ten or twenty nuclear weapon states is not one which I contemplate with anything but apprehension.

Furthermore, it seems likely that even if a country will not adhere to the NPT, its ability to develop an effective nuclear capability would be severely curtailed, if not entirely eliminated, if it were a party to a comprehensive nuclear test ban treaty. Japan, India, Israel and the United Arab Republic are examples of countries which are parties to the Limited Test Ban Treaty but not to the NPT. Adherence by those countries to a CTB would represent an important achievement in the pursuit of nuclear nonproliferation.

In addition, a CTB would eliminate the possibility of adverse environmental effects caused by underground nuclear testing. Finally, and most important, an effective comprehensive test ban would dampen the arms race by curtailing further improvements in nuclear warheads by the nuclear powers adhering to the Treaty, and it would be a natural supplement to agreements between the United States and the Soviet Union at SALT.

Military Considerations Bearing on a CTB

Although established United States policy has for many years supported the achievement of a comprehensive test ban adequately verified, the military considerations involved in that policy determination must be examined in any review of the prospects for a CTB. The factors weighing against a CTB are in essence the military corollaries of its principal advantage. One major argument advanced in opposition to a CTB is that it would preclude the improvement of our nuclear weapons stockpile which might in turn somehow hamper our ability to deter nuclear war.

Nevertheless, the weapons systems currently maintained by the United States are now adequate to deter a Soviet attack. To continue that capability, it should not be necessary to have the most efficient or sophisticated warheads theoretically available. In fact, precluding such improvements on both sides would be an effective way of insuring the continuation of that capability. In developing any new weapons systems which may become necessary, the configuration of such a system may have to be modified to fit a warhead already in the stockpile rather than using a newly developed optimum warhead which

could not be relied upon without testing. Of course, all the other components of the system could be tested, a much more important matter since the basic characteristics of nuclear reactions are well known. Therefore, while a CTB may preclude the "optimum" exploitation of new military technology, there is no evidence to suggest that it would fundamentally hinder the maintenance of a sufficient deterrence capability by the United States.

It can also be argued that we cannot maintain confidence in the continuing reliability of our existing warheads without continuous testing. The potential reliability problem is, however, put into perspective by information furnished by the Department of Defense to the Subcommittee as a result of the hearings. DOD stated that

> Validation tests of nuclear assemblies are not conducted after a warhead has entered the stockpile unless such tests are deemed necessary to determine performance degradation which is suspected because of evidence obtained in the stockpile sampling program, or to demonstrate that defects have been satisfactorily corrected.

There were only five principal cases since the mid-1950s cited by the Department of Defense where a nuclear test was an integral part of a corrective program, and the corrections involved were designed either to meet stricter safety standards or to correct a metallurgical or mechanical problem which developed after the warhead entered the stockpile. In a statement entitled "Stockpile Reliability in the Absence of Nuclear Testing" the Department of Defense added:

> [Stockpile] Reliability may be affected by decisions to incorporate seemingly acceptable improvements into nuclear assembly systems without validation from a nuclear test. Changes affecting reliability may also be made in an effort to correct a defect developing in a nuclear assembly system.

There is no question but that improvements in weaponry will be hindered by a CTB; that is, of course, one of the purposes of such a Treaty. Acceptance of a CTB necessarily entails foregoing even "seemingly acceptable" improvements to the stockpile if they present a serious threat to stockpile reliability. As to changes designed to correct a defect developing in a particular type of warhead, it would appear that if a CTB were implemented, such defects would have to be remedied by a previously tested method or by replacing the warhead *de novo*, thereby restoring whatever effectiveness it had at the time of its entry into the stockpile. The Department of Defense adds:

> Of course, the reliability of the stockpile will be affected by the willingness of the government to spend possibly large sums of money to work around recognized deficiencies without nuclear tests. With such funding available the loss in reliability could often be avoided or delayed, although in the absence of nuclear testing corrective measures might involve longer periods of system degradation and might involve settling for a warhead performance well off the optimum.

There may be significant economic costs attached to a CTB, but those costs would be minor in comparison to the benefits derived from a Treaty and the savings derived from not testing and indefinitely replacing warheads to match improvements by the Soviets.

An additional problem concerns the possibility that a potential defect would be discovered which was not the result of aging but was inherent (but unknown) in the warhead at the time it entered the stockpile. There is no doubt that it would be a very serious matter if a metallurgical or mechanical problem were discovered in one of the warheads in a strategic system, provided the problem could not be

corrected by substituting a completely rebuilt warhead (i.e., if the problem were not one which had developed merely as a result of aging). At the same time, it seems inconceivable, after all the testing which has been done by the United States to date, that such a fundamental problem could now exist in warheads which are part of our strategic systems. This appears to be one of the extremely improbable risks which we can afford to take, in view of the benefits of a CTB, assuming the other problems can be worked out. Furthermore, since nuclear testing is not primarily used to determine reliability of stockpiled weapons, the probability of discovering such a weakness would not be significantly affected by a CTB.

Any diminution of confidence in the reliability of a nuclear stockpile should operate with comparable effect on all nuclear powers which are parties to the Treaty, and hence a CTB could be a stabilizing factor which would actually enhance the existing state of mutual deterrence.* Furthermore, since the United States has conducted approximately four times as many tests as the Soviet Union since 1963 (based on the announcements of nuclear tests by the AEC), it would seem to follow that a CTB would leave the United States in an established position of significant relative advantage, another consideration favoring a CTB from the U.S. point of view.

THE VERIFICATION QUESTION

Reflecting the clear preponderance of considerations favoring a CTB, the policy of the Nixon Administration, as well as of preceeding Administrations, has been unequivocally in favor of a comprehensive test ban adequately verified. It is the requirement of adequate verification which has raised most of the difficult problems. This requirement is of central importance in considering whether to proceed with a CTB, since successful violations by the Soviet Union over a period of time could conceivably upset the existing military balance. The United States could not adhere to a CTB if the possibility of evasion by the Soviet Union were so great that the United States had no confidence that the Treaty's benefits were in fact being realized. In fact, widespread suspicion of clandestine testing, even though created by natural seismic events, could itself add to international tensions. At the same time, it is clear that no verification system can be implemented which will guarantee that no violation has occurred. There will always be a yield threshold below which the chance of detection is very low. This would be the case even if the Treaty called for on-site inspection. The concern with adequate verification is not directed to such an ambitious goal. The purposes of verification procedures are instead to deter a nation from conducting prohibited tests by rendering significant violations so likely to be discovered that a possible evader will not judge clandestine testing to be worth the risk. Therefore, an evaluation of what constitutes adequate verification is a highly inexact art since it depends on political judgments and unknown future conditions which could lead a nation to conclude that it was worth taking great risks to pursue a test program, as well as depending on the

*Since China would presumably not sign a CTB at this time, it would be free to pursue a complete nuclear program. In view of the enormous U.S. lead over China, this factor poses no problem at this time. Consideration should be given to inclusion of a procedure for review of the CTB at some future time (or at periodic intervals) if all nuclear powers are not then parties to the Treaty.

inherently uncertain capability of seismic monitoring systems (and other intelligence means) which could detect clandestine tests.

A significant portion of the current debate on verification has focused on whether it is possible to identify earthquakes and explosions down to a magnitude* of 4.0 on the Richter scale. Such a capability would undoubtedly increase our ability to detect clandestine violations of a Treaty and hence would have an incremental, if unquantifiable, effect on deterring such violations. Nevertheless, being able to identify earthquakes and explosions down to a magnitude of 4.0 should not be regarded in itself as a prerequisite of a comprehensive test ban or as a key which will solve all the problems inherent in the questions involved.

It should also be noted that the statement that a system has the capability of identifying earthquakes and explosions down to a given magnitude generally refers to a 90% incremental probability of identification of the stated magnitude. Just as there is no magic in the magnitude 4.0, there is no magic in the 90% probability factor. Even if there is less than 90% probability of identifying explosions at successively lower magnitudes, there will always be some prospect of identification and hence some deterrent effect on a potential evader. For example, a 50% probability, or even less, probably would be adequate for the very low magnitudes in view of the fact that a single test of small yield would have no effect on the strategic balance. The decreasing scale of probability of identification should be calculated for various yields detectable by various possible monitoring networks and should become part of the debate on a CTB.

In testimony before the Subcommittee, Professor James N. Brune pointed out that it is now theoretically possible to identify earthquakes and explosions down to a magnitude of about 4.0 on the basis of previously established discrimination criteria. He suggests that a new seismic monitoring system, using currently available instrumentation, could be constructed internationally to exploit this possibility. The executive branch's position on this issue has been articulated in a statement by Dr. Stephen Lukasik to the Conference of the Committee on Disarmament (CCD) at Geneva. The executive branch's approach is more cautious, but is not inconsistent with that of Dr. Brune as a matter of principle. The executive branch agrees that in principle the ability to identify earthquakes and explosions will continue below a magnitude of 4.5, although it does not commit itself to any specific lower limit. Dr. Lukasik also recognized that the exploitation of that capability would require a massive investment in new instrumentation:

> Improved seismic instrumentation is clearly needed to attain further advances below magnitude 4.5 and to assess the limits of teleseismic discrimination.
>
> We have seen that to translate the greater scientific understanding of the identification problem into improvements in the seismic verification capability requires more sophisticated installations than currently exist. * * * expansion of the existing network of seismic arrays and individual stations would seem highly desirable * * *
>
> Many of these improvements would undoubtedly require considerable time and they would represent a substantial capital investment. Much effort would have to go into determining where these additional facilities should be located in order to achieve maximum performance.

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*The size of the seismic event produced by either an explosion or an earthquake is normally described in terms of magnitude on the Richter scale which is determined by the amplitude of the seismic waves transmitted through the earth. Since magnitudes are expressed on a logarithmic scale, a change in magnitude of one represents a change in energy transmitted of 10.

Nevertheless, the executive branch does not propose to proceed at this time with the deployment of a new seismic monitoring network. By deferring such a move, it is apparently felt that the U.S. will gain time to assess the data produced by three large seismic arrays, two of which are just now becoming operative; and a companion program involving new instruments (for measuring very long period waves) at ten stations, four of which have not yet been completed. This will permit the testing of a variety of discrimination criteria, exploration of techniques to improve the effectiveness of discrimination criteria (enhancing surface to noise ratios) and improvement of means to locate seismic events. Time is also needed for completion of the necessary site surveys and agreements. Under the executive branch's approach, after approximately two years we will have greater understanding of the best design for a new network (which will depend on the discimination criteria chosen) and the optimum siting and distribution of instruments; and we will then have acquired useful experience in the actual operation of a large and complicated network, including experience with the automated data processing techniques which become increasingly important as lower magnitudes are approached.

It seems to be conceded by all that the capability of a seismic monitoring network can be developed to identify explosions down to somewhere in the neighborhood of magnitude 4.0. It is also clear that substantial investments in equipment will be necessary to implement that capability, although that cost, perhaps up to $200 million, is insignificant when compared to the amounts spent on arms and the value derived from a CTB.* Although we cannot be certain at this time that a new seismic monitoring network will attain the hoped for identification capability at magnitude 4.0, it seems highly probable that it will reach a capability near 4.0. Upon the deployment of such a system, it is clear that there would be a very powerful additional deterrent available to police a CTB.

On-Site Inspection

The executive branch insists that on-site inspection is indispensable to adequate verification of a CTB. On-site inspection would certainly create an additional inhibition against violations of a Treaty, but the question is how significant this would be and whether it is necessary. A factor which must weigh very heavily in the consideration of these issues is that, even without on-site inspection, a country would be inhibited from violating such a Treaty in view of the probable political and diplomatic consequences of being cuaght.

Furthermore, on-site inspection is useful only in dealing with a limited range of seismic events. On-site inspection is of no help in explaining events at the lower end of the magnitude range where the events cannot be detected (or in explaining events which cannot be located). And it is not necessary for events at the higher end of the range because seismic means should be adequate. To place the role of on-site inspection into proper perspective it would be helpful to have available calculations showing the numbers and magnitudes of events in which on-site inspection would be theoretically useful, assuming various seismic capabilities.

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* In every year since 1963 the AEC has spent over $250 million on the nuclear test program alone.

Other Factors To Be Considered

There will always be some ambiguous events of possible significance even above the identification threshold, but their number will decrease rapidly as magnitude increases. Since the number of such events will depend on the operating efficiency of the seismic monitoring systems deployed, the extent to which the number can be lowered from its present level is not now predictable with any degree of precision.

In weighing the risks inherent in a CTB, consideration must be given to the possibility of detection of violations by other means and to the military significance of violations. Some events can be eliminated from concern through the use of other diagnostic aids and inferences from other known factors, utilizing both seismic instruments and other intelligence means. Although these means of interpretation may only help eliminate events in an unpredictable or fortuitous fashion, their potential provides an additional deterrent against evasions. At the same time, there will always be some unidentified events, especially at the lower magnitudes.

In assessing the significance of unidentified events (or events below the identification threshold) other variables must also be considered. If the event is an explosion, the magnitude of the event does not reveal the yield of the exploded device. Extrapolating the yield from the magnitude of the event requires consideration of the soil in which the device is tested and the extent, if any, to which efforts have been made to "decouple" the impact of the explosion. According to Dr. Carl Walske, an explosion recorded at a magnitude 4.0 would be equivalent to about 1½ KT if the test were in granite or 12 KT if the test were in alluvium. At magnitude 4.5 the comparable figures are approximately 6 KT and 45 KT. Although an evader could thus maximize the chance of escaping detection by testing in alluvium or comparable dry "soft" soil, such soil would be the most likely to collapse or leave a crater at the surface after a test, which renders it more susceptible to detection by other intelligence means.

Of greater theoretical concern are possibilities of evasion. These possibilities include the use of a very large cavity in which to explode the device ("decoupling"), a technique which can be enhanced by encompassing the device with a material which will absorb energy from the blast to reduce the seismic waves. In addition, it is possible to explode the device in a seismically active area concurrently with an earthquake of great magnitude so that the seismic waves generated by the explosion become mixed with those from the earthquake (known as "hiding in an earthquake"). The first of those methods requires extensive activity and a substantial period of time to prepare. The larger the explosion, the larger the hole would have to be and hence the more activity involved and time required. The activities associated with any substantial clandestine testing program present great enough risks to constitute a significant impediment against exploiting these decoupling techniques. The other technique, hiding in an earthquake, poses formidable uncertainties with regard to the location and timing of explosions. The use of a number of large arrays and sophisticated seismic analysis presents a significant possibility of detection in the use of this technique as well. The same deterrent applies to the use of a coordinated succession of nuclear tests designed to simulate an earthquake.

Furthermore, it must be noted that the possibilities of successful evasion through any of the techniques mentioned are greatest at the low yield level where the military significance of testing, from the point of view of the overall strategic balance, is of lesser significance.* As yields (and hence military significance) increase, the possibility of evasion falls off. The practical ceiling for these techniques may not be significantly different from that resulting from the use of soft soil for testing. While the possibilities of evasion through decoupling or hiding in an earthquake cannot be ignored, on balance they seem to pose an acceptable risk far outweighed by the benefits to be derived from a CTB. Indeed it would seem that a CTB resting on seismic verification means alone would provide a high degree of assurance that high yield violations were not occurring, a defensible objective in itself.

Since 1963 many advances have been made, particularly in seismology, which make the time auspicious for a hard look at the continuing need for on-site inspection. It is clear that the deployment of a variety of seismic stations and arrays would add considerably to the deterrent available to police a CTB. At the same time, there are a number of problems which must be explored further, including the timing and other details involved in achieving optimum results from the deployment of new instrumentation, the deterrent effects achievable by the network deployed, and the handling of peaceful nuclear explosions.

Peaceful Nuclear Explosions

A major impediment to a CTB is posed by the possible continuation of peaceful nuclear explosions (PNE). Since it would be possible to pursue weapons development in conjunction with a PNE program, it must be recognized that the possibilities of evasion through these means are at least as serious as the problems inherent in seismic identification. There does not appear to have been any exploration of the amenability of other nations to the idea of a total ban on all nuclear explosions, including those for peaceful purposes. Since this would seem to be inconsistent with the expectations of many non-nuclear countries, and in view of the active Soviet PNE program, it may be that a ban including peaceful explosions is impractical. On the other hand, if on-site inspection were eliminated as an issue, perhaps it would be possible to induce other states to forego the limited potential benefits of peaceful nuclear explosions as a price required to be paid for a CTB.

If not, the most promising procedure would seem to involve supervision of peaceful nuclear explosions by the International Atomic Energy Agency or a new international body established for the purpose. There would be many problems such as the mechanics of supervision, control of instrumentation, supply and control of the nuclear device, timing of the explosion and composition of the decision-making body. Negotiation of these problems would inevitably consume a considerable period of time, during which it would be possible to acquire additional confidence in seismic identification possibilities and to assess the true capability of the entire seismic network as deployed.

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*For example, warheads for the Soviet SS-9 and SS-11 produce yields measured in hundreds or thousands of kilotons.

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