NOTE

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

The report of the Conference of the Committee on Disarmament was originally submitted to the General Assembly and the Disarmament Commission under the symbol A/9141-DC/236.
## CONTENTS

<table>
<thead>
<tr>
<th>ABBREVIATIONS</th>
<th>Paragraphs</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>iv</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INTRODUCTION</th>
<th>1 - 3</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. ORGANIZATION OF THE CONFERENCE</td>
<td>4 - 6</td>
<td>1</td>
</tr>
<tr>
<td>A. Procedural arrangements</td>
<td>4 - 5</td>
<td>1</td>
</tr>
<tr>
<td>B. Participants in the Conference</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. WORK OF THE COMMITTEE DURING 1973</th>
<th>7 - 154</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Further effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament</td>
<td>12 - 39</td>
<td>2</td>
</tr>
<tr>
<td>B. Non-nuclear measures</td>
<td>40 - 103</td>
<td>6</td>
</tr>
<tr>
<td>C. Other collateral measures</td>
<td>104 - 115</td>
<td>16</td>
</tr>
<tr>
<td>D. Question of general and complete disarmament</td>
<td>116 - 154</td>
<td>18</td>
</tr>
</tbody>
</table>

| III. SPECIAL REPORT ON THE QUESTION OF A TREATY BANNING UNDERGROUND NUCLEAR WEAPON TESTS | 155 - 183 | 24   |

## ANNEXES

<table>
<thead>
<tr>
<th>I. DOCUMENTS ISSUED BY THE CONFERENCE OF THE COMMITTEE ON DISARMAMENT</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. DOCUMENTS OF THE CONFERENCE OF THE COMMITTEE ON DISARMAMENT ANNEXED TO THE REPORT TO THE GENERAL ASSEMBLY</td>
<td>33</td>
</tr>
<tr>
<td>III. LIST OF VERBATIM RECORDS OF THE MEETINGS OF THE CONFERENCE OF THE COMMITTEE ON DISARMAMENT</td>
<td>234</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>ALPA</td>
<td>Alaskan Long-Period Array</td>
</tr>
<tr>
<td>ARPA</td>
<td>United States Advanced Research Projects Agency</td>
</tr>
<tr>
<td>AWRE</td>
<td>Atomic Weapons Research Establishment (United Kingdom)</td>
</tr>
<tr>
<td>CANSAM</td>
<td>The Canadian Seismic Array Monitor System</td>
</tr>
<tr>
<td>EDR</td>
<td>Earthquake Data Reports</td>
</tr>
<tr>
<td>EURATOM</td>
<td>European Atomic Energy Community</td>
</tr>
<tr>
<td>ISC</td>
<td>International Seismological Centre (Edinburgh)</td>
</tr>
<tr>
<td>ISM</td>
<td>International Seismic Month Project</td>
</tr>
<tr>
<td>LASA</td>
<td>Large Aperture Seismic Array in Montana (USA)</td>
</tr>
<tr>
<td>NOAA</td>
<td>United States National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NORSAR</td>
<td>Norwegian Seismic Array</td>
</tr>
<tr>
<td>PDE</td>
<td>Preliminary Determination of Epicentres</td>
</tr>
<tr>
<td>SASP</td>
<td>Seismic Array Stations Processor</td>
</tr>
<tr>
<td>SIPRI</td>
<td>Stockholm International Peace Research Institute</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-noise ratio</td>
</tr>
<tr>
<td>SRO</td>
<td>Seismic Research Observatories</td>
</tr>
<tr>
<td>VLPE</td>
<td>Very-Long-Period Experiment</td>
</tr>
<tr>
<td>WWSSN</td>
<td>World-Wide Standard Seismological Network</td>
</tr>
</tbody>
</table>
INTRODUCTION

1. The Conference of the Committee on Disarmament submits to the United Nations General Assembly and to the United Nations Disarmament Commission a progress report on the Committee's deliberations on all questions before it for the period 20 February to 30 August 1973, together with the pertinent documents and records.

2. This report includes accounts of the Committee's work during 1973 on further effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament, non-nuclear measures, including the question of the prohibition of chemical weapons, other collateral measures, and general and complete disarmament under strict and effective international control.

3. A special report on the question of a treaty banning underground nuclear weapons tests is set forth in section III below.

I. ORGANIZATION OF THE CONFERENCE

A. Procedural arrangements

4. Two sessions were held, the first from 20 February to 26 April 1973, and the second from 12 June to 30 August 1973. During this period, the Committee held 42 formal plenary meetings, during which members set forth the views of their Governments and recommendations for progress on the questions before the Committee. The Committee also held four informal meetings without records.

5. In addition to the plenary meetings, members of the Committee met frequently for informal multilateral consultations on disarmament questions of common interest.

B. Participants in the Conference

6. Representatives of the following States continued their participation in the work of the Committee: Argentina, Brazil, Bulgaria, Burma, Canada, Czechoslovakia, Egypt, Ethiopia, Hungary, India, Italy, Japan, Mexico, Mongolia, Morocco, Netherlands, Nigeria, Pakistan, Poland, Romania, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland, United States of America and Yugoslavia.

II. WORK OF THE COMMITTEE DURING 1973

7. In a letter dated 11 February 1973, the Secretary-General of the United Nations transmitted to the Conference of the Committee on Disarmament the resolutions on disarmament questions adopted by the General Assembly at its twenty-seventh session.
8. Members of the Committee were assisted in their examination and analysis of possible disarmament measures by working papers, other documents that were submitted to the Conference of the Committee on Disarmament (annexes I and II) and the plenary statements of Committee members (annex III).

9. At the opening plenary meeting of the 1973 session, the Special Representative of the Secretary-General of the United Nations presented a message to the Conference from the Secretary-General. In his message, the Secretary-General said that the more favourable political climate that now exists should help the Conference of the Committee on Disarmament in its efforts to achieve further progress. He expressed the hope that the momentum which had led to the achievement of a number of important multilateral arms control agreements between 1963 and 1971 could and would be sustained and would produce further concrete results. The Secretary-General expressed the view that the stage has now been reached where it would be of evident usefulness for all concerned to move on to concrete negotiations in working towards the complete realization of the objective of effective prohibition of chemical weapons, as stated in General Assembly resolution 2933 (XXVII). He also expressed his conviction that a comprehensive test-ban treaty is an indispensable step in the efforts to halt the nuclear arms race. The Secretary-General said he was confident that the Committee would continue its constructive work and would make every possible effort to engage in concrete negotiations on the most urgent issues before it and with a view to achieving new agreements.

10. The Committee continued work in accordance with its provisional agenda on the following measures in the field of disarmament.

   (a) Further effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament;

   (b) Non-nuclear measures;

   (c) Other collateral measures;

   (d) General and complete disarmament under strict and effective international control.

11. A number of members of the Committee referred to the question of a World Disarmament Conference.

   A. Further effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament

12. Members of the Committee continued their work in 1973 on questions relating to the cessation of the nuclear arms race.

13. In accordance with General Assembly resolution 2934 B (XXVII), a special report on the results of the Committee's deliberations on a treaty banning underground nuclear weapon tests has been prepared and is set forth as section III of the present document.
14. Some delegations noted General Assembly resolution 2936 (XXVII), entitled "Non-use of force in international relations and permanent prohibition of the use of nuclear weapons".

15. The delegation of the Union of Soviet Socialist Republics stated that this resolution was a significant step on the way to placing nuclear weapons outside the law and expressed the hope that the Security Council would take early measures in connexion with this resolution. It also stated that the Soviet Union is prepared to agree upon and appropriately to formalize reciprocal commitments with any of the nuclear Powers on the non-use of force, including the prohibition of the use of nuclear weapons against one another (CCD/PV.585).

16. The delegation of the United States of America referred to recent new parties to the Treaty on the Non-Proliferation of Nuclear Weapons and to progress in negotiating a safeguards agreement between IAEA and EURATOM. It expressed the hope that the countries concerned would move towards ratification of the Treaty and that additional States would accede to the Treaty (CCD/PV.585).

17. The delegation of Mexico recalled that, in General Assembly resolution 2932 B (XXVII), the General Assembly had appealed to the Governments of the Union of Soviet Socialist Republics and the United States of America to make every effort to expedite the conclusion of further agreements including important qualitative limitations and substantial reductions of offensive and defensive strategic nuclear-weapon systems (CCD/PV.585).

18. The delegation of the United Kingdom expressed the hope that recent ratifications of the Treaty on the Non-Proliferation of Nuclear Weapons would be matched elsewhere in the world, thereby strengthening the Treaty as a cornerstone of nuclear stability (CCD/PV.587 and 619).

19. The delegation of Japan said that the Committee should give highest priority to nuclear disarmament and reiterated that, out of all aspects of nuclear disarmament, the Committee should promote a comprehensive test ban with utmost attention (CCD/PV.588).

20. The delegation of Romania emphasized that the negotiations in the Committee should be focused on nuclear disarmament problems as a matter of priority, advocating the elaboration of a concrete programme for prohibiting the use of nuclear weapons, the cessation of their production and their destruction under international control (CCD/PV.592 and 613).

21. The delegation of Mexico called attention to the importance of the countless appeals of the General Assembly for the cessation of the nuclear arms race and for nuclear disarmament. It also commented on the subject of nuclear deterrence and reiterated its view on the importance of observing all the provisions of General Assembly resolution 2932 B (XXVII) concerning the bilateral talks between the Union of Soviet Socialist Republics and the United States of America on strategic arms limitation, including those relating to the necessity of keeping the General Assembly
informed of the results of their negotiations (CCD/PV.589 and 617). The delegation tabled a document (CCD/394) concerning these talks.

22. The delegation of Canada expressed the view that the Co-Chairmen had a clear duty to put before the Committee proposals for a ban on all nuclear weapons testing and regretted that two nuclear Powers did not participate in the Committee's discussions (CCD/PV.591).

23. The delegations of Czechoslovakia (CCD/PV.589 and 611), Hungary (CCD/PV.590), Poland (CCD/PV.591), Mongolia (CCD/PV.592), the Soviet Union (CCD/PV.596, 603 and 609) and Bulgaria (CCD/PV.601) pointed to the necessity of an early ratification of, or accession to, the Treaty on the Non-Proliferation of Nuclear Weapons by all States and, first of all, by those possessing the material and technical capabilities for developing nuclear weapons.

24. The delegation of Romania requested that the problem of security guarantees for non-nuclear States be considered and appropriately settled during the disarmament negotiations (CCD/PV.592 and 613).

25. The delegation of the Netherlands referred to the signing, on 5 April 1973, of the Safeguards Agreement between Belgium, the Federal Republic of Germany, Italy, Luxembourg, the Netherlands, EURATOM and IAEA and stated that it was proof of progress in the implementation of the Treaty on the Non-Proliferation of Nuclear Weapons and of the international control system connected therewith (CCD/PV.598).

26. The delegation of the Netherlands urged the widest possible adherence to the Treaty on the Non-Proliferation of Nuclear Weapons and stressed that the Treaty had to be considered a starting point for further negotiations to curb the nuclear arms race. It expressed the view that significant progress in the field of nuclear arms limitation or disarmament would be needed to secure the viability of the Treaty and that otherwise it could be in danger or would at least not be accepted by some States (CCD/PV.608).

27. The delegations of Sweden (CCD/PV.601) and the Netherlands (CCD/PV.608) noted the necessity of preparing for the Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons. The delegation of the United Kingdom commented that it was the responsibility of the depositary Powers to initiate the Review Conference and set suitable administrative arrangements in hand after appropriate consultations with other parties (CCD/PV.625).

28. The delegation of the Union of Soviet Socialist Republics (CCD/PV.609) stressed that the outcome of the 1973 Soviet-American summit talks is the indication of further considerable efforts made by their participants in order to achieve maximum progress in implementing the obligations stipulated in article VI of the Treaty on the Non-Proliferation of Nuclear Weapons.

29. The delegation of Egypt stressed the interest of the whole of mankind to ensure the replacement of the current precarious and dangerous state of affairs by a system
of a true nuclear disarmament banning tests, development, manufacture and use of nuclear weapons (CCD/PV.619).

30. The delegation of Sweden called for a halt to the development of a new generation of small tactical nuclear weapons and stated that an absolute firebreak must be kept up between nuclear and conventional war. The main purpose of the Treaty on the Non-Proliferation of Nuclear Weapons to reduce the risks of nuclear war — would otherwise be countered (CCD/PV.620).

31. The delegation of Italy expressed the view that the problem of halting the nuclear arms race and moving towards nuclear disarmament should be more incisively considered in the United Nations and in the appropriate organs. It also emphasized that the solution of this problem requires the active and responsible participation of all the nuclear Powers (CCD/PV.621).

32. The delegation of the United Kingdom said that the United Kingdom Government had always been conscious and remained very conscious of the importance in political as well as military terms of the distinction between nuclear and conventional weapons. So far as the United Kingdom was concerned, no decision had been taken to develop, test or deploy a new generation of small-yield tactical nuclear weapons (CCD/PV.625).

33. The delegation of the United States expressed the view that nations have a common stake in preserving and strengthening the Treaty on the Non-Proliferation of Nuclear Weapons and that no one could gain by taking action that might weaken the Treaty. It expressed the conviction that the Treaty could and would continue to be a constructive and positive force in international relations and said the United States would do everything it could towards the continuing fulfilment of the Treaty's fundamental purposes (CCD/PV.626).

34. Some delegations noted the importance of the Soviet-American Agreement on Prevention of Nuclear War (A/9293, annex I).

Other measures

35. The question of nuclear-free zones was also discussed.

36. The representatives of the Soviet Union (CCD/PV.585), Mexico (CCD/PV.585 and 603), Hungary (CCD/PV.590), Poland (CCD/PV.591), Romania (CCD/PV.592), Bulgaria (CCD/PV.594) and Japan (CCD/PV.607) supported the establishment in various regions of the world of nuclear free zones.

37. The delegation of Romania reiterated its proposal for the establishment in the Balkans of a zone of peace and co-operation free of nuclear weapons, and stressed the importance of strengthening security and co-operation in that region with a view to promoting détente and peace in Europe (CCD/PV.592 and 613).
38. The delegation of Mexico (CCD/PV.603), representing the depository Government of the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco), stated that, during the visit of the head of the Mexican State to France and the People's Republic of China, the Governments of those countries declared their intention of signing Additional Protocol II of the Treaty of Tlatelolco. The delegation subsequently drew attention to the interpretative declarations accompanying the French Government's (CCD/PV.617) as well as the Chinese Government's (CCD/PV.625) adherence to the Protocol. The delegation stressed the fact that, after the steps thus taken by those two Governments, there would remain only one nuclear Power which had not yet heeded the repeated appeals of the General Assembly to sign and ratify the Protocol (CCD/PV.617 and 625).

39. The delegations of Japan (CCD/PV.588 and 607), Romania (CCD/PV.592), the United States (CCD/PV.603) and the Netherlands (CCD/PV.608) favoured the conclusion of an agreement to stop the production of enriched uranium for military purposes and also the conversion of the existing stockpiles of such uranium and the installations for its production to peaceful use. The delegation of Japan also appealed to all nuclear Powers to sign Additional Protocol II of the Treaty of Tlatelolco.

B. Non-nuclear measures

Question of chemical and bacteriological (biological) weapons

40. Having in mind the recommendations of the General Assembly in its resolution 2933 (XXVII), the Conference of the Committee on Disarmament continued its efforts to achieve progress on all aspects of the problem of the elimination of chemical weapons. Members of the Committee emphasized the importance and urgency which they attach to the prohibition of chemical weapons.

41. Possible steps for progress in this field were discussed by members of the Committee in their plenary statements and working papers.

42. The delegation of the United States reiterated that the United States Government is fully committed to the goal of effective controls on chemical weapons. It expressed the view that the Conference of the Committee on Disarmament had already succeeded in sorting out and identifying key issues in the chemical weapons area, but that there were a number of issues that warranted further attention and analysis by the Committee (CCD/PV.585).

43. The delegations of Bulgaria, Czechoslovakia, Hungary, Mongolia, Poland, Romania, and the Soviet Union, co-authors of the draft convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction of 28 March 1972, 1/ continued to advocate an early beginning of concrete negotiations with a view to elaborating a generally acceptable draft convention. They emphasized that, while proposing their draft as a basis for negotiations, they were ready to consider any reciprocal proposals aimed at achieving this task. They also stated that it was concrete proposals of this nature that could be a constructive contribution to the negotiations rather than comments of a general character (CCD/PV.611, 612, 616 and 617).

44. The delegation of Mexico reaffirmed its position to the effect that, had a
criterion as rigorous as the one which some delegations would like to apply to
chemical weapons been applied to biological weapons, the Convention on the latter
would not have been completed by the year 2000. The delegation also reiterated that
the method, recommended by the group of non-aligned countries 2/ since 1970, of a
"combination of suitable national and international measures" seemed to be fully
adequate for solving the verification problem (CCD/PV.585).

45. The delegation of the United Kingdom said that its desired aim was an effective
comprehensive ban. It expressed the view that it was wrong and an
over-simplification to say that only a political decision was needed to get on with
the matter because in fact there were difficult technical problems still to be
solved (CCD/PV.587). It hoped that, in view of the many constructive comments made
by delegations on document CCD/361, the Soviet Union would come forward with new
proposals in February 1974 (CCD/PV.625).

46. The delegation of the Soviet Union, commenting on the above statement,
stressed that the reason for the impasse in the negotiations lay in the attitude
of some Western countries which so far have failed to suggest positive proposals
on concrete formulations of a future agreement (CCD/PV.626).

47. A number of delegations expressed the view that the problem of the prohibition
of chemical weapons had been considered from all sides and that the time had come
to proceed to the elaboration of a generally acceptable agreement for the
prohibition of chemical weapons.

48. The delegation of the Netherlands expressed the hope that the Committee's
common thoughts and efforts might pave the way for making at least a first step
towards chemical weapons disarmament. It expressed the view that the Committee
should move from the stage of explorations to the stage of negotiations (CCD/PV.589).

49. The delegation of Morocco said that the delegation of the United States had
placed before the Committee a number of important documents dealing in particular
with the technical aspects of the prohibition of chemical weapons, and appealed
to it to submit specific proposals in the form of amendments to the draft
convention submitted by the Socialist countries or to submit a new draft convention
so that the Committee could begin active negotiations on this question without
delay (CCD/PV.592).

50. The delegation of Nigeria said that the Committee could draw from the wealth
of knowledge that was now available to it with a view to seriously and positively
engaging its members in substantive negotiations. It expressed the conviction that
enough was now known on the subject and that the time was ripe for the Committee to
start immediate negotiations in a concrete form and with a draft treaty or draft
the treaties before it. It also held the opinion that the draft submitted by
Socialist countries, with all its pointed inadequacies, should form the basis of
immediate negotiations if, as expected, no other one was forthcoming. It, however,
nursed the hope that the Socialist countries' action would serve as an impetus for

2/ Known as the Group of Twelve.
the Western Powers or the United States to submit its own treaty text, to the extent that history would have to repeat itself as was the case for the convention on biological weapons two years ago (CCD/PV.594).

51. The delegation of Yugoslavia said that a comprehensive agreement on measures for prohibiting the development, production and stockpiling of chemical weapons and for their destruction represented an unchanged position of its Government and that all efforts should be concentrated on finding the best possible ways and means of eliminating the stockpiles from the arsenals of those States which possess them. The delegation said that it was aware of the complexity and difficulties of certain aspects of the complete prohibition of chemical weapons and of their destruction but suggested there were a number of issues on which there was a consensus and that these should be identified and recorded. In its view, the proposals and suggestions submitted so far contained replies to almost all questions that should be dealt with in the provisions of the future agreement. It expressed the view that it would be of both substantive and political importance for the elaboration of a draft convention on the prohibition of chemical weapons for the United States delegation to submit its proposals in any appropriate form which might facilitate further progress. It suggested the establishment of an ad hoc international body of experts of different specialities to elaborate proposals for the procedure and method of verification (CCD/PV.595 and 616).

52. On 26 April, the delegations of Argentina, Brazil, Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia submitted a working paper on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction (CCD/400). The working paper sets forth general provisions which, in the view of these delegations, any agreement banning chemical weapons should entail, such as avoidance of any detraction from the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, signed at Geneva on 17 June 1925, avoidance of any hampering of the peaceful uses of chemical agents, an undertaking not to assist others in prohibited activities, promotion of the fullest possible exchange of chemical technology for peaceful purposes, utilization of savings derived from disarmament, and security guarantees. The working paper also sets forth views on the scope of the prohibition, on verification and the system of control, and on a complaints procedure. In submitting the working paper on behalf of its co-sponsors, the delegation of Sweden termed it a concrete contribution to negotiations on banning chemical weapons (CCD/PV.603).

53. The delegation of Egypt expressed the view that the draft submitted by the socialist countries would provide a sound basis for the start of negotiations on the question of chemical weapons. It said such negotiations should also draw on the extremely useful documents submitted to the Committee by various delegations and in this connexion accorded a special place to the points put forward on several occasions by non-aligned members. The delegation added that the aim should be to seek to reach an agreement on a treaty for the general prohibition of these weapons, covering all chemical agents and activities capable of being used for military purposes, and that one could adopt a realistic method of establishing the detailed arrangements for the implementation of such a treaty (CCD/PV.603).

54. The delegation of the United States said that it regarded the working paper as a concrete contribution to progress in negotiations. It expressed agreement with the working paper's first four paragraphs concerning the Geneva Protocol, peaceful applications, assistance to third parties and promotion of exchanges for peaceful purposes. It expressed reservations on the working paper's provisions regarding security guarantees and savings (CCD/PV.608).

55. The delegations of Poland, Czechoslovakia (CCD/PV.611) and the Soviet Union (CCD/PV.612) expressed the view that the provisions of the working paper in many aspects coincided with the position of the socialist countries or were close to one another.

56. The delegation of Sweden recommended that the Geneva Protocol of 1925 should be strengthened by its parties through the withdrawal of the existing reservations (CCD/PV.620).

57. On 21 August, the delegation of Japan tabled a working paper (CCD/413) on the main points of an international agreement on the prohibition of the development, production and stockpiling of chemical weapons and their destruction. The paper includes suggestions for a treaty which prescribes a comprehensive ban and for a supplementary document determining what the scope of the initial prohibitions will be. The treaty would contain a provision for national verification measures and another under which international verification would be conducted. Details of these measures would be provided in the supplementary document. Treaty provisions concerning the Geneva Protocol, consultation and co-operation among the parties, entry into force and duration would be drafted in conformity with the corresponding provisions of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction. 4/ In tabling the working paper, the delegation of Japan expressed the view that the paper represented the highest common factor of the opinions of the members of the Committee at the present stage of discussions on chemical weapons (CCD/PV.623).

58. The delegation of Brazil said that it was impossible to negotiate on the principle that a substantial portion of the savings derived from measures of disarmament should be used to promote economic and social development, particularly in the developing countries. Only the manner of its application could be the object of negotiation in relation to a concrete measure of disarmament (CCD/PV.625).

59. The delegation of the United States expressed the view that the working paper tabled by the delegation of Japan (CCD/413) represented a constructive effort which it would study carefully and seriously. It regarded the gradual approach of the Japanese proposal in directly relating the scope of the activities prohibited to the possibilities of verification as a more practical and realistic approach than some others. The delegation also expressed the view that the Japanese proposals for the establishment of an international verification organ and for "inspection by co-operation" represented a step in the right direction, though further elaboration and exploration were needed before their effectiveness could be judged. The delegation stated that the United States was practising restraint in its own chemical weapons programme in that it had not produced any chemical weapons since 1968 and has been phasing out parts of its chemical weapons stockpile for years (CCD/PV.626).

4/ General Assembly resolution 2626 (XXVI), annex.
60. Close attention was devoted by the delegations to the scope of possible measures for prohibition of chemical weapons.

61. The delegations of Bulgaria, Czechoslovakia, Hungary, Mongolia, Poland, Romania and the Soviet Union continued to support the comprehensive prohibition of the development, production and stockpiling of chemical weapons as weapons of mass destruction, in accordance with their draft convention (CCD/361).

62. The delegation of the United Kingdom said that it wished to see a simultaneous destruction of all stockpiles of chemical weapons and needed to be satisfied that all had been destroyed. It wished to see a complete cessation of the production of chemical weapons and had to be satisfied that this cessation really was complete (CCD/PV.587).

63. The delegation of Canada said that, given the technical difficulties, the question arose whether it would be better to continue to seek a comprehensive ban, which might involve lengthy negotiations, or whether the Committee should give thought to an initial partial measure, such as a ban on the development, production and stockpiling of the most lethal agents or a ban on certain activities, such as production. The delegation expressed the view that the Committee, without losing sight of its long-term goals, should take steps that are now possible (CCD/PV.591).

64. The delegation of Brazil expressed the view that the opportunity for more immediate progress in the Committee's deliberations on chemical weapons might well lie in the pragmatic approach of concentration on the discussion of problems that might open the way for a two-step treaty beginning with the destruction of stockpiles. In the view of the Brazilian delegation, by proceeding gradually and partially the Committee may be in a better position to avoid discrimination between countries at different levels of technological development and of military preparedness. In other words, the Brazilian delegation thinks that the Committee must begin by negotiating actual measures of disarmament and not measures of non-armament, as suggested recently (CCD/PV.597).

65. The delegation of Italy stated that its previous statements and working papers on scope and control (CCD/PV.579, CCD/335 5/ and 373 6/) remained valid and that it would examine with an open mind all other proposals which might be put forward which seemed likely to help negotiations (CCD/PV.600 and 621).

66. The delegations of Argentina, Brazil, Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia stated in a working paper (CCD/400) that the negotiations relating to chemical weapons should aim at reaching a comprehensive ban covering the development, production and stockpiling of all chemical weapons, their equipment and means of delivery, as well as the destruction of existing stocks. They considered that, since adequate protection against any kind of chemical weapons was not available to the greater part of the world population, even less-toxic agents could create as great a danger as highly toxic ones and therefore should be prohibited. They also stated that a partial solution with respect to the scope of the activities to be prohibited, which would only ban the development and


6/ Ibid., Supplement for 1972, document DC/235, annex B.
production of chemical weapons, would be particularly discriminatory and would not be acceptable to many countries, especially to those which have abstained from procuring such weapons.

67. The delegation of the United States expressed its intention to participate in exploring further what possibilities might exist for achieving an adequately verified agreement for the comprehensive prohibition of chemical weapons. It said that it believed that consideration should continue to be given to possible partial measures also, since earlier studies and interventions had, in its view, demonstrated that the difficulties in achieving adequate verification of a comprehensive agreement might be very great (CCD/PV.604).

68. The delegation of the United States said that it saw some practical consideration in support of the idea put forward by Japan that an initial agreement be limited to the most toxic substances. It added, however, that it recognized the concerns expressed in the 10-nation working paper (CCD/400) concerning the significant danger which less-toxic substances could constitute and said that it would welcome further discussion of this problem (CCD/PV.608).

69. The delegation of the United States expressed the view that the achievement of a balanced agreement involved the assessment of many provisions, including verification, and not merely those relating to scope. It also expressed the view that it was premature to reach a conclusion that a measure focused on production would be particularly discriminatory. It was necessary to consider, inter alia, what various parties would gain and give up under a measure as well as its effect on regional and world-wide security. The delegation therefore expressed the hope that all members of the Committee would work in accordance with the spirit of paragraph 9 of the working paper (CCD/400) in seeking an acceptable balance of obligations and responsibilities for all States (CCD/PV.609).

70. The delegation of Sweden underlined that special formulations would be needed in a treaty on chemical weapons to ensure that also binary chemical weapons were covered. If not all equipment and means of delivery for all chemical weapons were prohibited in a treaty, the efficacy of the prohibition and its verification system would be greatly reduced (CCD/PV.622).

71. The delegation of Japan, in plenary statements and in commenting on its working paper (CCD/413), said that its desired ultimate aim was to put a comprehensive ban on chemical weapons, but that there were difficulties in reaching such a ban in one stroke. Accordingly, its working paper suggested a treaty, calling for a comprehensive ban, together with a supplementary document which would temporarily limit the ban to the development and production of super-toxic agents. The treaty would include a provision by which parties undertake to continue negotiations in good faith in order to agree at the earliest date on concrete measures for realizing a comprehensive ban. The delegation stated that, because of verification limitations, stockpiling should be excluded temporarily from the treaty's prohibitions, but that it was logical to expect that a ban on stockpiles would be achieved later when effective measures of verification were attainable (CCD/PV.594, 607 and 623).
72. Some delegations commented on the various criteria proposed for the determination of the scope of a prohibition.

73. The co-sponsors of working paper CCD/400 affirmed that a comprehensive prohibition could deal with the problem of scope by a general purpose criterion while more detailed provisions could be elaborated in the annexes of the treaty.

74. The delegation of the United States, commenting on the working paper (CCD/400), said that it agreed in general with the idea that a general purpose criterion could be a basic element of the principal obligations of a comprehensive treaty and suggested that the question of how to deal with possible more detailed standards required further discussion and analysis (CCD/PV.609).

75. The delegations of the Socialist countries, co-sponsors of the draft convention (CCD/361), continued to support the purpose criterion which was included in that draft. The delegation of the Soviet Union expressed the view that the comprehensive prohibition of chemical weapons on the basis of the purpose criterion was the most suitable both for reasons of principle - in the light of the objective of achieving a total prohibition of this type of weapon of mass destruction - and for practical reasons, since it would mean adopting the simplest and clearest formula which is not open to contradictory interpretations (CCD/PV.612).

76. The delegation of Sweden stated that the binary production technique made it even more necessary to base a production ban on a purpose criterion (CCD/PV.622).

77. The delegation of Japan proposed that the agents to be prohibited in the comprehensive treaty suggested in working paper CCD/413 be defined by a general-purpose criterion. The agents to be covered by the initial ban under the terms of the supplementary document would be decided by objective criteria, such as toxicity and general structural formulae (CCD/PV.623).

78. The delegation of Canada suggested that a general-purpose criterion in a comprehensive treaty might be supported by a technical scheme of definition of lethal chemical warfare agents based on levels of toxicity of chemicals. It was suggested that two thresholds of toxicity might be set - one to include the super-toxic agents, the production of which could be banned, while a second lower threshold might encompass agents of less toxicity, the production of some of which might be permitted by agreement for civil purposes, but the use of which in military munitions and delivery devices could be prohibited. The scope of a treaty in terms of the development, production and stockpiling of chemical weapons would have to be considered in the light of the adequacy of the proposed verification system (CCD/PV.623).

79. Considerable attention was devoted in the course of the work of the Committee to the question of control over the observance by States, parties to a future agreement, of the obligations assumed by them for the prohibition of chemical weapons.
80. The delegation of the United Kingdom said that the chief problem and key to all progress in this field was verification and the provision of adequate guarantees to those States which agreed to give up any chemical weapons which they might possess and to renounce their right to possess them in future. Referring to a complaints procedure, the delegation expressed the belief that it would be necessary to make a clear and firm distinction between the factual investigation of a complaint and the procedure for taking decisions in the light of the facts reported (CCD/PV.587).

81. The delegation of Japan expressed the view that on-site inspections were necessary in case of a comprehensive prohibition of chemical weapons and that, if the countries concerned could not accept such inspection, it would be necessary to turn to other possibilities such as the separate prohibition of specific activities (CCD/PV.588).

82. On 6 March, the delegation of Sweden submitted a working paper (CCD/395) elaborating its concept of amplified verification in relation to the prohibition of chemical weapons.

83. The delegation of Sweden expressed the view that the convention on biological and toxin weapons was not in all respects a suitable model for chemical weapons. It stated that, in a convention on chemical weapons, the need was even greater for a complaints procedure, where the fact-finding was distinctly separated from the final political decisions or judgement made by the Security Council. It also expressed the view that the absence of any continuous verification measures would not be acceptable in a convention on chemical weapons (CCD/PV.590).

84. Many delegations, in the course of discussion in the Committee, spoke in favour of a combination of national and international forms of control over the observance of the agreement.

85. The delegation of the Soviet Union expressed the view that there was a general understanding that the problem of control should be solved not on the basis of any one method, but through a reasonable combination of national and international measures of control. The delegation stated that this approach was offered in the draft convention of the socialist countries, which envisaged the possibility of using a number of national means of verification in combination with some international procedures, which, however, should not serve as means of unjustified interference in the internal affairs of States (CCD/PV.593).

86. The working paper of the seven socialist countries (CCD/403) developed provisions of article IV of their draft convention (CCD/361) relating to a system of national control and dealt with such possible elements of that system as national control committees, exchange of information, statistical analysis and patent limitations.

87. The working paper of 10 non-aligned delegations (CCD/400) expressed the view that a control system should be based on a combination of national and international measures and include (a) the self-control of States, including declarations of

\[7/ \text{Ibid.}\]
national activities related to production and to destruction of stockpiles, (b) national means of verification and (c) international measures of verification performed by a qualified and independent international organ with the results available to all parties on an automatic and fact-finding basis.

88. The delegation of Mongolia stated that international meetings of experts of States parties to a future agreement could play a useful role, inter alia, by submitting suggestions and recommendations to periodic review conferences on matters connected with the discovery of new chemical products and trends in research and providing, on the basis of Security Council decisions, expert assistance in solving problems relating to complaints as provided for in article VI of the draft convention submitted by the socialist countries (CCD/361).

89. The delegation of Egypt said its preference was for a system of control which would consist of an adequate combination of national and international control and verification measures. It expressed the view that international co-operation would contribute to an improved verification system and the dissemination of information and that it would be useful to establish a qualified and independent international body which would be called upon to perform the functions described in working paper CCD/400 (CCD/PV.603).

90. The delegation of Romania emphasized that any system of safeguards and controls, established by a convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction, should in no way prejudice the security and peaceful development of States (CCD/PV.608).

91. The delegation of the United States posed a number of questions about the proposal in working paper CCD/400 for inspection to verify the destruction of stockpiles. It expressed views on the problems caused by uncertainties about the extent of stockpiles and by the considerable time required to destroy a substantial arsenal. The delegation expressed the view that a chemical weapons treaty procedure governing the destruction of stockpiles should be the subject of prior agreement and not left until after the treaty's entry into force (CCD/PV.609).

92. The delegation of Poland considered extremely important the view expressed in working paper CCD/400 that the purpose of the verification system should be to give every party a reasonable assurance of compliance with the prohibition. Otherwise it would be very easy to go to extremes and to call for verification systems developed ad absurdum (CCD/PV.611).

93. The delegation of the Soviet Union expressed the view that on-site inspections did not guarantee the observance by States of the treaty prohibiting chemical weapons and would lead to obvious difficulties of a political and technical character. The connexion of the production of chemical substances for military and for peaceful purposes made international inspections impracticable (CCD/PV.612).

94. The delegation of the United States, commenting on working paper CCD/400, agreed with its statement that assurance of compliance with the prohibitions of an agreement could be provided through a combination of national and international
measures. While agreeing that declarations could have considerable value in a system of verification, it offered suggestions regarding particular types of declarations. It stressed that there ought to exist international verification procedures which could be utilized to ascertain the facts regarding treaty observance and that fact-finding procedures should be of an effective and objective character (CCD/PV.613).

95. On 31 July, the delegation of the Netherlands presented a working paper (CCD/410) on an international organ for implementation of a chemical weapons convention to which responsibilities in other disarmament fields could also be allocated in the future. The delegation stated that such a body would have the merit of dividing the process of verification into two phases, separating fact-finding from political decisions. It could serve as a medium for the exchange of views before complaints would be lodged with the Security Council (CCD/PV.617).

96. The delegation of the United States discussed the working paper submitted by Sweden (CCD/395) and raised questions concerning the extent of the applicability of the Swedish concept of amplified verification to the problem of verifying a comprehensive prohibition on chemical weapons (CCD/PV.618).

97. On 14 August, the Special Representative of the Secretary-General distributed a working paper (CCD/412) by the Government of Finland on the progress of the Finnish project for the creation of a national basis of a chemical weapons control capacity for possible future international use.

98. The delegation of Czechoslovakia expressed the view that a system of control should be such that under no circumstances could it be used for the violation of sovereignty of any State party to the agreement or for interference in its internal affairs (CCD/PV.621).

99. The delegation of Sweden said that there seemed to exist a consensus within the Committee on the need for international consultations in connexion with a ban on chemical production and suggested that this idea was ripe for a concrete decision (CCD/PV.622).

100. In its working paper (CCD/413), the delegation of Japan suggested a treaty with a supplementary document, providing for a combination of national and international verification measures, involving an international verification organization and "inspection by co-operation". The organization could request inspection in cases where national verification and requests for explanation had not satisfied States parties with regard to the compliance of others with the treaty's obligations. The delegation suggested that the international verification organization might include a verification committee composed of States parties which were members of the Conference of the Committee on Disarmament. It stated that, if members of the Committee engaged directly in verification, they would be able to judge whether the verification provisions of the treaty were effective and whether further progress could be made towards a comprehensive ban on chemical weapons agents and activities (CCD/PV.623).
101. The delegation of the Netherlands, in referring to the functions which an international organ could fulfil in support of a convention on chemical weapons, expressed the view that there would be no question of infringement of national sovereignty if States, in the free exercise of their sovereignty, agreed to allot to some organ certain rights to be exercised on their territory which could eventually be withdrawn if abused (CCD/PV.62).

102. The delegation of the United States expressed the view that the verification provisions of the draft convention submitted by Bulgaria, Czechoslovakia, Hungary, Mongolia, Poland, Romania and the USSR (CCD/361), which were elaborated in their working paper (CCD/403), were essentially self-inspection and did not provide the effective international verification necessary to assure that an agreement would contribute to security and stability (CCD/PV.62).

103. The delegation of the Soviet Union noted that the presentation by some delegations of impracticable requirements regarding control, in fact, created an obstacle in the way of progress to negotiating appropriate measures to limit armaments and on disarmament (CCD/PV.62).

C. Other collateral measures

104. The delegation of Mexico pointed out that, if the existing stagnation on the two priority questions assigned to the Committee were unfortunately to subsist, it would be advisable to select some other specific topics for study and negotiation, such as the reduction of military budgets, a measure which the General Assembly itself had strongly recommended as early as 1950 (CCD/PV.585).

105. The delegations of Czechoslovakia (CCD/PV.589), Poland (CCD/PV.591 and 624) and Romania (CCD/PV.592 and 613) favoured discussion of the question of reducing the military budgets. The delegation of Romania urged the Committee to take the initiative in examining this subject, especially in view of the further consideration by the General Assembly at its forthcoming session of the economic and social consequences of the armament race (CCD/PV.592 and 613).

106. The delegations of Yugoslavia (CCD/PV.616) and Sweden (CCD/PV.620) proposed that a study of ways and means to reduce military expenditures should be organized.

107. The delegation of the United States said that the Committee, without detracting from its efforts regarding weapons of mass destruction, had a duty as an international organization devoted to the cause of peace to promote a timely exchange of views which might result in effective and mutually advantageous controls over conventional weapons. Referring to the many conflicts involving conventional weapons since the end of the Second World War, the delegation expressed the view that development of restraints on these weapons was an urgent matter (CCD/PV.585 and 603).

108. The delegation of the United Kingdom, noting that it had sometimes been suggested that agreements to control the trade in conventional arms might be one way to reduce the burden imposed by armaments, stressed that the effectiveness of
such agreements would require the co-operation and active support of recipient as well as supplier countries (CCD/PV.587).

109. The delegation of the Netherlands spoke for a regional approach to the question of limiting conventional armaments (CCD/PV.589).

110. The delegation of Czechoslovakia expressed the view that the task of limiting the conventional weapons could only be achieved through the realization of the proposal for the renunciation of the use of force in international relations and the prohibition of the use of nuclear weapons for all times (CCD/PV.589).

111. The delegation of Morocco expressed the view that final solution to the problem of conventional weapons could be found only in the global framework of general and complete disarmament, not only because this question was of a lesser degree of gravity than that of weapons of mass destruction, but also because the problem of conventional weapons was closely linked to the security, and even to the independence and territorial integrity, of a number of States which did not possess nuclear weapons. The delegation went on to say that the question of conventional weapons could not be dealt with separately from the problem of the enormous production and development of such weapons, or from the flourishing trade in them (CCD/PV.592).

112. The delegation of Nigeria said that, while it was not completely oblivious of the fact that other disarmament or arms control measures, like conventional arms and reduction in military budgets, were also germane to the work of the Committee — subjects to which it would contribute its views in a concrete and positive manner when the time was ripe — it shared the conviction that negotiations in the current phase of the work of the Committee should concentrate on the most important questions related to nuclear and other weapons of mass destruction and not on less pressing matters (CCD/PV.594).

113. The delegation of Egypt adhered to the priorities established by the resolutions of the General Assembly, particularly resolutions 2933 (XXVII) and 2934 (XXVII). It declared that, in spite of the importance of problems connected with conventional weapons, their discussion at a time when no progress had been made with regard to weapons of mass destruction might make the task of the Committee more difficult and make a rather pointless addition to the collection of unfinished works (CCD/PV.603).

114. The delegation of Yugoslavia stated that the arms race consumed enormous and ever growing human, financial and technological resources and that military expenditures had increased year by year. It noted that there was a close link between international security, disarmament and economic development and pointed to the necessity to engage in an organized manner in a study of ways and means of reducing the astronomic sums wasted on military expenditure (CCD/PV.595 and 616).

115. The delegation of Brazil said that ever since détente between the super-Powers had become manifest and had been expressed in acts and deeds of greater significance, the justification for preliminary and collateral measures, based on the recognition that they strengthened détente and stimulated further measures of real disarmament, had lost most of its cogency (CCD/PV.625).
D. Question of general and complete disarmament

116. The delegation of the Netherlands considered that it was necessary to direct efforts to reaching general and complete disarmament (CCD/PV.589).

117. The delegation of Romania considered it necessary to resume talks aimed at preparing a treaty on halting the arms race and achieving general disarmament (CCD/PV.592).

118. The delegations of Romania (CCD/PV.592 and 613) and Czechoslovakia (CCD/PV.611) appreciated the fact that a number of positive results had been achieved in promoting détente and peace in Europe and stressed the importance of the Conference on Security and Co-operation in Europe. The delegation of Romania also expressed the view that military disengagement and disarmament in that region constituted a fundamental problem of European security. It formulated a number of concrete measures to be taken to this end.

119. The delegations of Italy (CCD/PV.600) and Romania (CCD/PV.592 and 613) expressed the view that a disarmament programme should be worked out maintaining a constant link between the partial measures and the final goal of general and complete disarmament under effective international control. In this regard, the delegation of Italy stated that all Members of the United Nations should submit their own draft programmes or put forward proposals to pave the way for a negotiation leading to a treaty on general and complete disarmament (CCD/PV.600 and 621).

120. The delegation of Mexico expressed its regret that the nuclear Powers appeared to have forgotten the goal of general and complete disarmament, and said that this objective nowadays only occasionally received from them the verbal tribute of a timid, incidental and hasty reference (CCD/PV.619). The delegation added that the General Assembly should ask the USSR and the United States, as recommended in the comprehensive programme of disarmament, to revise and update the draft treaties submitted to the Eighteen-Nation Committee on Disarmament in 1962, and that this new draft should be submitted to the Assembly or the Conference of the Committee on Disarmament (CCD/PV.625).

121. The delegation of Brazil stated that progress in the Conference of the Committee on Disarmament had been achieved only on measures that were not militarily significant to the great Powers and which dispensed with direct international controls. The only exception being the Treaty on the Non-Proliferation of Nuclear Weapons, which established strict and mandatory on-site controls through the IAEA safeguards system. It expressed the view that both super-Powers found that, in that case, direct international verification methods were politically feasible and indispensable for reassurance, provided they applied to non-nuclear-weapon States alone (CCD/PV.625).

122. The delegation of the United Kingdom raised the question as to whether measures of disarmament were a means of creating confidence or a consequence of already established confidence. It observed that measures of disarmament could contribute
to the building of confidence where they could be effectively verified and that the degree of control or verification required would vary with the degree of confidence developed. It said this applied not only in the context of a comprehensive test ban, but of all other disarmament questions as well (CCD/PV.599).

123. The delegation of Yugoslavia stated that it would be useful to re-examine the possibilities of new approaches to the whole complex problem of disarmament, pointing to the comprehensive programme of disarmament recommended in General Assembly resolution 2661 C (XXV) as containing all necessary elements to serve as such a basis. It further suggested that the delegations of the USSR and the United States should be asked to revise and bring up to date their programmes for general and complete disarmament (ENDC/2 8/ and 30 9/) and that, at its forthcoming session, the General Assembly should be invited to give serious consideration to new approaches to, and new starts in, the whole problem of disarmament (CCD/PV.616).

124. The delegation of the United States expressed the view that the accomplishments of the Conference of the Committee on Disarmament included not only the agreements it had achieved but the influence it has had on the ways in which Governments think about arms and disarmament. It also expressed the view that, in arms control agreements, verification was a substitute for full trust and that it was inadvisable to build up verification schemes which presupposed full trust among Governments. It stated that so-called "national means" of verification, therefore, must not only be capable of producing the requisite observations or data, but also must be entrusted to the party or parties that wish to reassure themselves and not to the parties about which the reassurance is being sought (CCD/PV.617).

* * *

125. A number of delegations commented on the question of the organizational forms of disarmament negotiations and expressed views regarding the desirability of the participation of all nuclear-weapon States in disarmament efforts.

126. On 14 March, the delegations of Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia submitted a memorandum (CCD/396) to the Committee in which they expressed the view that the Committee, which was the main multilateral negotiating body for disarmament, was of fundamental importance to the United Nations and the world community. They expressed their increasing concern over the lack of tangible progress in the solution of the main disarmament problems entrusted to the Committee, a situation which had become apparent during its last session and which the meetings of the present session had so far confirmed. While reiterating that it was most desirable that all nuclear-weapon States participate in disarmament negotiations, they reaffirmed their opinion that the non-participation of two of those States in the work of the Conference of the
Committee on Disarmament should not prevent it from discharging its obligations. They also expressed their conviction that there was no reason which might justify any stagnation of the Committee's work and the current absence of effective negotiations, especially on the questions of cessation of all nuclear-weapon tests and the prohibition of chemical weapons, which the General Assembly has repeatedly requested the Committee to deal with as matters of "first" or "high" priority. Negotiations in the current phase of the work of the Committee should, therefore, concentrate on the most important questions related to nuclear and other weapons of mass destruction and not on less pressing matters.

127. The delegation of Romania called for the improvement of the organization and procedures of the Conference of the Committee on Disarmament with a view to ensuring the effectiveness of the negotiations on disarmament, the democratization of the activity of the Conference and its submission to effective public control. It urged the widening of the range of concrete topics for negotiations by according equal receptivity and consideration to all views and proposals submitted in the Committee (CCD/PV.592 and 613).

128. On 23 August, the delegation of Mexico submitted a document, entitled "Working paper containing a compilation of statements made on the stagnation of the Committee's work, the absence of effective negotiations, and other related matters", at the formal meetings of the Conference of the Committee on Disarmament held from 20 February to August 1973 (585th to 622nd meetings) (CCD/415).

129. The delegation of Mongolia stated that non-participation of certain nuclear Powers in the negotiations on disarmament was a hindrance to the achievement of further measures in the field of disarmament, particularly nuclear disarmament (CCD/PV.592).

130. The delegation of Romania expressed its concern at the absence of progress in the work of the Committee, manifesting its anxiety at the escalation of the arms race while the disarmament negotiations stagnate (CCD/PV.592 and 613).

131. The delegation of Argentina stated that nothing definite had been done which would mean real disarmament and that what had been achieved were mainly measures of non-armsament or armament limitation. It also expressed the view that effective disarmament could be achieved only with the co-operation of all countries and that nuclear disarmament, whose overriding priority was not even under discussion, was inconceivable without the participation or assent of all the Powers possessing nuclear weapons (CCD/PV.600).

132. The delegation of Yugoslavia stated that its Government attached great importance to the timely and complete implementation of General Assembly resolution 2930 (XXVII) and that, at its forthcoming session, the General Assembly might therefore undertake to resolve the problem of an adequate and effective preparatory body, which could pave the way for the early convening of the World Disarmament Conference with the participation of all States. It expressed the view that, if all efforts towards this end remained fruitless, it would be indispensable to convene urgently a session of the United Nations Disarmament Commission in order to realize the generally acceptable objective, as set forth in General Assembly resolutions 2833 (XXVI) and 2930 (XXVII) (CCD/PV.595 and 616).

133. This proposal was supported by the delegation of Sweden, which spoke in favour of convening the United Nations Disarmament Commission in the spring of 1974 if
it should turn out that agreement on convening the World Disarmament Conference could not be reached (CCD/PV.610).

134. The delegation of Romania (CCD/PV.613) also supported the view of the delegation of Yugoslavia on this question. It referred to the need for steps to be taken to increase the capacity and efficiency of the United Nations in implementing practical measures to reduce and destroy armaments and nuclear weapons above all (CCD/PV.613).

135. The delegation of Sweden called for consideration of the establishment of an interim International Disarmament Organization. It should act as a clearing-house for providing knowledge as to implementation of disarmament agreements and keep a constant watch over progress in the direction of disarmament. It could also assure the fairness and objectivity of verification procedures. The organization could start monitoring relevant activities before a treaty was entered into, and this might, in fact, stimulate the emergence of the treaty (CCD/PV.601 and 610). The delegation submitted a working paper (CCD/398) presenting the ways in which verification had been dealt with in various arms control and disarmament treaties and proposals.

136. The delegation of Poland believed that it would be inadvisable to create permanent bureaucratized organs and that negotiations on international procedures should be conducted within the framework of the existing organizations (CCD/PV.611).

137. The delegation of Italy expressed the view that, rather than by a multiplication of organs and procedural instruments, which might prove to be a snare and merely increase difficulties, significant progress towards a lasting peace could be achieved only by a new approach to the disarmament problem, making full use of the multilateral organs now in existence (CCD/PV.621).

138. The delegation of Sweden expressed the view that it was necessary to broaden the horizons of disarmament and drew attention to areas in which fresh efforts were needed, that is, the demilitarization of the sea-bed and a curtailment of national military activities in the international ocean space. The delegation expressed concern about the danger posed by the possible development of completely new weapons and methods of warfare and stressed the need to abolish, or at least contain, the use of not only incendiary weapons, but also other weapons which were particularly cruel or indiscriminate (CCD/PV.620).

139. The delegation of the Netherlands, in discussing the question of the structure and form of a negotiating body, expressed the view that one should not rush for a large meeting if there were no guarantee that it would result in much more than an unproductive and harsh debate. The delegation also expressed the view that, while the Conference of the Committee on Disarmament might not have any agreements to report to the General Assembly, it was doubtful that any other multilateral and broadly representative body could have achieved results that would have been very different (CCD/PV.624).

140. The delegation of Poland supported the view that the Committee should actively consider a wide range of collateral measures suggested over the years, one of them being the question of the renunciation of the use of force in international relations and the permanent prohibition of the use of nuclear weapons, in
accordance with General Assembly resolution 2936 (XXVII), adopted on the initiative of the Soviet Union (CCD/PV.624).

141. The delegation of Mexico suggested that the General Assembly set up a committee or working group, which should strive to reach conclusions regarding whether it would be advisable to reorganize the negotiating body available to the United Nations, that is, the Conference of the Committee on Disarmament, as soon as possible or, on the other hand, if it would be better to wait until the World Disarmament Conference was held before taking those steps. Regardless of the conclusions reached in this respect, the delegation further suggested that the committee or working group could undertake immediately the examination of the reforms, which, both with regard to membership and to procedure, it deemed appropriate to recommend in order to render the negotiating body more effective and, in particular, in order to ensure the participation of all nuclear Powers (CCD/PV.625).

142. The delegation of the Soviet Union stated that, despite the lack of practical results in the work of the Committee for the last year or two, the Committee remained a necessary and useful international forum for the consideration of disarmament problems. The serious and thorough character of discussions in the Committee attracted attention not only of States members of this body, but also of a great number of States which are not represented in the Committee. In fact, the Committee had become a generally recognized international forum for the examination and co-ordination of States' actions aimed at limiting the arms race and achieving disarmament (CCD/PV.626).

* * *

143. Some delegations also devoted attention to the question of a World Disarmament Conference.

144. The delegation of the Soviet Union expressed the view that the holding of such a conference would considerably stimulate negotiations on disarmament problems in all international forums and bodies, including the Conference of the Committee on Disarmament. It expressed the hope that, in the final count, all of the nuclear Powers would adopt a constructive attitude towards the question of convening the conference and would contribute to its positive results (CCD/PV.585, 590, 594 and 604).

145. The delegation of Mexico reiterated its support for the proposal to convene a World Disarmament Conference open to all States. The delegation expressed the view that, owing to the unfortunate situation derived from the divergent positions of the nuclear Powers, the only hope that the Special Committee on the World Disarmament Conference could have carried out its mandate would have been by having its membership made up exclusively of States which did not possess nuclear weapons, and it regretted that this solution had not been accepted by all the nuclear Powers (CCD/PV.585 and 594). The delegation further suggested that the General Assembly should endeavour at its twenty-eighth session to establish, following informal negotiations, a new committee which might receive the co-operation of all nuclear Powers (CCD/PV.625).
146. The delegation of the United Kingdom reminded the Committee that the sponsors of General Assembly resolution 2930 (XXVII) had expressed the unanimous view that the participation of the five nuclear weapon States was essential in order to ensure the success of the Special Committee's work. It was the view of the United Kingdom Government that the Special Committee on the World Disarmament Conference should meet only when all five nuclear weapon States were ready to take their seats (CCD/PV.587). It questioned the value, as a stop-gap, of a premature meeting of the United Nations Disarmament Commission which could not guarantee the active participation of all the nuclear weapon States in the attempt to negotiate concrete measures. Quiet diplomacy should be continued (CCD/PV.625).

147. The delegations of Czechoslovakia (CCD/PV.589), Hungary (CCD/PV.590), Poland (CCD/PV.591), Mongolia (CCD/PV.592) and Bulgaria (CCD/PV.594) expressed the view that the participation of all the nuclear Powers in the World Disarmament Conference and in the work of the Special Committee was of great importance; however, the fact that some of them were not yet ready to take their seats on the Special Committee should not prevent it from beginning its work. They appealed to the members of the Conference of the Committee on Disarmament to do everything for the successful beginning and constructive work of the Special Committee on the World Disarmament Conference.

148. The delegation of Morocco stated that Morocco continued to believe that this Conference should be held, with the participation of all States, including the five nuclear Powers, and was prepared at any time to take part in the work of the Special Committee (CCD/PV.592).

149. Support for the World Disarmament Conference was also expressed by the delegations of Nigeria (CCD/PV.594), Brazil (CCD/PV.597), India (CCD/PV.600) and Romania (CCD/PV.592 and 613).

150. The delegation of Brazil expressed, furthermore, the view that the Special Committee on the World Disarmament Conference should be activated in a manner consistent with the purpose of the relevant resolution of the General Assembly (CCD/PV.597). In this connexion, the delegation of Brazil stood by the letter addressed to the Secretary-General of the United Nations by the Latin American Group in New York (A/9041).

151. The delegation of Argentina expressed support for the proposal to convene a World Disarmament Conference open to all States and attended by the five nuclear-weapon Powers. It expressed a critical view of the consultations that had taken place as regards the Special Committee on the World Disarmament Conference. It also stated that no real contribution could be made to the World Disarmament Conference or to disarmament problems in general in the absence of four of the five nuclear Powers or against their will.

152. The delegation of Argentina further stated that, prior to those consultations and the convening of the Special Committee, the most urgent task was to concentrate efforts on the Powers which refused to take part in it and which had the obligation and responsibility of proposing alternative solutions. In any case, the delegation considered it essential to create conditions to attract to the negotiating bodies -
and not to discourage — those Governments which were not yet represented in them (CCD/PV.600).

153. The delegation of Sweden expressed the view that the first and foremost task of the forthcoming session of the General Assembly should be to take a positive decision to call a World Disarmament Conference. If this could not be achieved, then in Sweden's view Yugoslavia's proposal of convening the United Nations Disarmament Commission next spring should be taken up (CCD/PV.610).

154. The delegation of Italy expressed the view that, once the necessary conditions for its convening were fulfilled, a World Disarmament Conference could provide a useful forum in which all members of the international community, including all the nuclear Powers, could meet to examine together the complex problems of disarmament (CCD/PV.621).

III. SPECIAL REPORT ON THE QUESTION OF A TREATY BANNING UNDERGROUND NUCLEAR WEAPON TESTS

155. In resolution 2934 B (XXVII), the General Assembly requested the Conference of the Committee on Disarmament to give first priority to its deliberations on a treaty banning underground nuclear weapon tests, taking full account of the views of experts and of technical developments bearing on the verification of such a treaty, and to submit a special report to the General Assembly at its twenty-eighth session on the results of its deliberations on this matter. Having in mind the request of the General Assembly, members of the Committee, during 1973, continued to work on the question of a treaty banning underground nuclear weapon tests. Many delegations spoke in favour of the early achievement of a comprehensive prohibition on the testing of nuclear weapons.

156. The delegation of the Soviet Union stressed that the aim pursued by its Government was to ensure the cessation of all nuclear weapon tests everywhere and by everyone, including the underground tests. It noted that, for control over the cessation of underground tests, national means of detection and identification would be sufficient to guarantee properly the observance by States of the obligations assumed by them for cessation of such tests (CCD/PV.585, 596 and 604).

157. The delegation of the United States stated that it continued to support the objective of an adequately verified agreement to ban all nuclear weapon testing and reaffirmed its view that, despite the substantial progress in detecting and identifying seismic events, including underground tests, national means of verification still should be supplemented by some on-site inspection. The delegation described the principal areas where the United States was making progress regarding the verification problem and said the United States was devoting substantial resources to help find solutions to the problems which persist (CCD/PV.585 and 604).
158. The delegation of the United Kingdom affirmed that an adequately verified comprehensive test ban treaty and the cessation of all nuclear test explosions for weapons purposes in all environments and by all countries remained the objective of all its efforts in this field (CCD/PV.625).

159. The delegation of Mexico stressed that the General Assembly had already adopted 24 resolutions on the question. The delegation added that in one of the latest resolution 2934 C (XXVII) - the General Assembly had reiterated "with the utmost vigour its condemnation of all nuclear weapon tests"; had also reaffirmed its conviction that there was no valid reason for delaying the conclusion of a comprehensive test ban; and had fixed 5 August 1973 (a date corresponding to the tenth anniversary of the partial test ban treaty) as the deadline for bringing to a halt all those tests (CCD/PV.585).

160. On 24 April, the delegation of Japan submitted a working paper (CCD/399) on problems in determining the body-wave magnitude.

161. The delegations of Hungary (CCD/PV.590), Poland (CCD/PV.591), Bulgaria (CCD/PV.594 and 601), Morocco (CCD/PV.592), Nigeria (CCD/PV.594), Sweden (CCD/PV.600 and 614) and Czechoslovakia (CCD/PV.611) expressed the view that modern means of seismic identification of underground nuclear explosions were sufficient for the purposes of verifying the agreement banning underground testing.

162. The delegation of the Netherlands expressed the view that the present and proved possibilities of seismological identification of underground nuclear explosions were sufficient to deter a would-be violator of an underground test ban, except perhaps for very small explosions (CCD/PV.608).

163. The delegations of Japan (CCD/PV.588), Sweden (CCD/PV.590 and 614) and Canada (CCD/PV.591) noted the importance of further studies of the possibilities of seismic measures of detection and identification of seismic events for the purposes of verifying the observance by States of the agreement for the comprehensive prohibition of nuclear testing, as well as the necessity of arranging multilateral and effective international co-operation in the field of seismology.

164. The delegation of India (CCD/PV.600) reiterated the four main considerations to be kept in mind for progressing towards the comprehensive test ban. In the first instance, the provisions of the partial test ban treaty should be fully observed, and those nuclear weapon States which have not yet adhered to that Treaty should do so without any further excuse or delay. Secondly, whatever the differences on the issue of verification of a ban on underground nuclear-weapon tests and notwithstanding any other considerations, all testing of nuclear weapons in all environments must be immediately suspended. Thirdly, a comprehensive test ban has two requirements: (a) all nuclear-weapon tests in all environments should be prohibited; and (b) all nuclear-weapon States should be parties to it. Fourthly, negotiations should be undertaken for a separate treaty to prohibit all nuclear-weapon tests in the underground environment, and attention should simultaneously be focused on the need to conclude an agreement on underground nuclear explosions for peaceful purposes.
165. Some delegations spoke for certain partial measures for the cessation of underground nuclear testing, such as prohibition of underground nuclear tests above some threshold which could be detected and identified by seismic methods (Japan - CCD/PV.588); for a moratorium on all testing (Sweden - CCD/PV.590 and 600); for the reduction of size and number of tests conducted (Canada - CCD/PV.591); and for a unilateral suspension of nuclear tests (Nigeria - CCD/PV.609).

166. The delegation of Egypt stressed the importance of a comprehensive test ban to the discontinuance of the arms race (CCD/PV.619) and stated that the question of banning underground nuclear-weapon tests should be studied in the light of the pertinent resolutions of the General Assembly, of the scientific and technological progress achieved in the matter of seismographic detection and identification and of the agreements on data exchange (CCD/PV.603).

167. On 28 June, the delegation of the United Kingdom submitted a working paper (CCD/401) on a review of the United Kingdom seismological research and development programme and a working paper (CCD/402) on the estimation of depth of seismic events. These documents were presented for discussion at the informal meetings.

168. The delegation of the Soviet Union stated that observations regarding the prohibition of underground tests by separate, partial steps or unilateral actions on the part of nuclear Powers, as well as establishing a certain yield threshold for underground tests, did not form a basis for the solution of the task of the comprehensive nuclear test ban (CCD/PV.596).

169. While emphasizing the need for concluding urgently a comprehensive test ban, the delegation of Pakistan reiterated the views of its Government on the question of peaceful nuclear explosions (CCD/PV.602).

170. The delegation of the Netherlands stated that it did not see the advantages of a partial solution to the nuclear test ban problem. The delegation said, however, that, if there were still some doubt about identification capabilities near the detection threshold, it was ready to support the Japanese idea of a threshold solution (CCD/PV.608).

171. The delegations of Japan (CCD/PV.588 and 609), Hungary (CCD/PV.590), Sweden (CCD/PV.590), Poland (CCD/PV.591), Canada (CCD/PV.591 and 609), Morocco (CCD/PV.592 and 609), Mongolia (CCD/PV.592 and 609), the Soviet Union (CCD/PV.596), India (CCD/PV.600), the Netherlands (CCD/PV.609), Nigeria (CCD/PV.609) and Czechoslovakia (CCD/PV.619) stressed the need for all the nuclear Powers to adhere to the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water.

172. The delegation of Mexico appealed to all the nuclear Powers to heed the call of humanity and to put an end, immediately and for all time, to nuclear-weapon tests whether in the atmosphere or underground (CCD/PV.609).

173. The delegation of the United Kingdom drew the attention of the Committee to the declaration of the Heads of Government of the Commonwealth, who met in Ottawa,
which included a phrase "reaffirming their unfailing support for the treaty /Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water/ and their concern to ensure its universal observance" (CCD/PV.619).

174. The delegation of Mongolia expressed its concern and regret in connexion with the continued nuclear atmospheric tests (CCD/PV.609 and 619).

175. On 10, 11, 12 and 13 July, informal meetings took place, at the request of the delegation of Japan supported by a number of other delegations, with the participation of technical experts from nine Member States. A discussion of questions pertaining to the verification of the comprehensive prohibition of nuclear tests took place at those meetings. Some members of the Committee found these informal meetings of value in promoting their work on the question of a comprehensive test ban. The following documents were presented for discussion at the informal meetings (see annex II below):

CCD/397 (Sweden): Working paper with points to be considered by experts on the verification of a ban on underground nuclear explosions.

CCD/404 (United States of America): A programme of research related to problems in seismic verification.

CCD/405 (Sweden): Working paper reviewing recent Swedish scientific work on the verification of a ban on underground nuclear explosions.


CCD/408 (Japan): Working paper on comparison between earthquakes and underground explosions observed at Matsushiro Seismological Observatory.

CCD/409 (Italy): Some observations on detection and identification of underground nuclear explosions - prospects of international co-operation.

176. The delegation of Yugoslavia expressed the view that a treaty banning underground nuclear weapon tests should be concluded without further delay. It also said that, in the absence of a comprehensive test ban, the possibility of proliferation of nuclear weapons continued to be a growing threat to international security and peace, despite the entry into force in 1970 of the Treaty on the Non-Proliferation of Nuclear Weapons. It expressed the view that a comprehensive test ban would have a direct and indirect beneficial effect as regards curbing the nuclear arms race, would increase the chances of world-wide acceptance of the non-proliferation treaty and would remove some of the objections in relation to that treaty by a number of non-nuclear-weapon States (CCD/PV.616).
The 619th plenary meeting was designated a special meeting on the occasion of the 10 years that had passed since the opening for signature of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water, which took place in Moscow on 5 August 1963. Statements were made by 20 delegations expressing views on the significance of the Treaty and on the need for a comprehensive test ban. Many of these delegations expressed their disappointment that the commitment in the Treaty to seek to achieve the discontinuance of all nuclear weapon tests for all time still remained unfulfilled and their apprehensions as to the consequences of a continued nuclear arms race. Some delegations also expressed their concern that this could undermine the viability of this Treaty and the non-proliferation treaty. A number of delegations expressed the view that the Treaty was an important step in reducing world tensions, that it had contributed to several agreements negotiated in the Conference of the Committee on Disarmament and that it had helped to make possible other arms control negotiations now under way.

The delegation of Italy expressed the view that closer international co-operation in the field of seismology could be decisive in improving the capabilities of the existing methods of control, thus facilitating a comprehensive test-ban convention. In view of the difficulties still hindering achievement of such a convention, the delegation was of the opinion that appropriate partial measures, strengthening mutual trust, might pave the way to its attainment in the very near future (CCD/PV.621).

On 31 July, the Special Representative of the Secretary-General distributed a working paper by the Government of Norway (CCD/411) on seismic research at the Norwegian Seismic Array (NORSAR).

On 28 August, the delegation of the Netherlands submitted a working paper (CCD/416) containing some observations on the verification of a ban on underground nuclear test explosions.

The delegation of the United States expressed the view that the informal meetings held from 10 to 13 July 1973 had been exceptionally valuable, having helped clarify certain questions concerning the capabilities and limitations of seismology for verification of a comprehensive test ban. The delegation expressed the belief that there could and would be events that were detected and located, but that were not identified by seismic means alone. It reaffirmed that the United States was prepared to give up whatever advantages might exist in continuing testing if this were done pursuant to an adequately verified treaty so that it could have reasonable confidence that other parties to the Treaty had given up the same advantages (CCD/PV.625).

The Committee agreed to reconvene on a day to be established by the Co-Chairmen in consultation with all members of the Committee.

The present report is transmitted by the Co-Chairmen on behalf of the Conference of the Committee on Disarmament.

(Signed) A. A. ROSCHCHN
Union of Soviet Socialist Republics

(Signed) Joseph MARTIN (Jr.)
United States of America
ANNEX I

Documents issued by the Conference of the Committee on Disarmament*

By a letter dated 11 February 1973, the Secretary-General of the United Nations transmitted to the Co-Chairmen of the Conference of the Committee on Disarmament the resolutions on disarmament adopted by the General Assembly (CCD/393).

By a letter dated 20 February 1973, the leader of the delegation of Mexico transmitted a letter, dated 3 November 1972 from the Chairman of the delegation of Mexico to the twenty-seventh session of the General Assembly, to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament (CCD/394).

On 6 March 1973, the representative of Sweden submitted a working paper on the concept of amplified verification in relation to the prohibition of chemical weapons (CCD/395).

On 14 March 1973, the representatives of Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia submitted a memorandum on the Conference of the Committee on Disarmament (CCD/396).

On 24 April 1973, the representative of Sweden submitted a working paper with points to be considered by experts on the verification of a ban on underground nuclear explosions (CCD/397).

On the same date, the representative of Sweden submitted a working paper presenting the ways in which verification has been dealt with in various arms control and disarmament treaties and proposals (CCD/398).

On the same date, the representative of Japan submitted a working paper on problems in determining the body-wave magnitude (CCD/399).

On 26 April 1973, the representatives of Argentina, Brazil, Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia submitted a working paper on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction (CCD/400).

On 28 June 1973, the representative of the United Kingdom of Great Britain and Northern Ireland submitted a working paper on a review of the United Kingdom seismological research and development programme (CCD/401).

* With the exception of document CCD/417, which contains the draft report of the Conference of the Committee on Disarmament, and document CCD/418, which contains the final report, all of the documents of the Conference of the Committee on Disarmament for 1973 appear in annex II.
On the same date, the representative of the United Kingdom submitted a working paper on the estimation of depth of seismic events (CCD/402).

On the same date, the representatives of Bulgaria, Czechoslovakia, Hungary, Mongolia, Poland, Romania and the Union of Soviet Socialist Republics submitted a working paper on the ways of implementing control over compliance with the convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction (CCD/403).

On 5 July 1973, the representative of the United States of America submitted a programme of research related to problems in seismic verification (CCD/404).

On 10 July 1973, the representative of Sweden submitted a working paper reviewing recent Swedish scientific work on the verification of a ban on underground nuclear explosions (CCD/405).

On the same date, the representative of Canada submitted a working paper on the verification of a comprehensive test ban by seismological means (CCD/406).

On the same date, the representative of the United States of America submitted a working paper containing comments on document CCD/399, concerning magnitude determinations (CCD/407).

On the same date, the representative of Japan submitted a working paper on a comparison between earthquakes and underground explosions observed at the Matsushiro Seismological Observatory (CCD/408).

On the same date, the representative of Italy submitted a working paper containing some observations on detection and identification of underground nuclear explosions - prospects of international co-operation (CCD/409).

By a letter dated 16 July 1973, the Permanent Representative of Norway transmitted to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament a working paper by the Government of Norway on seismic research at the Norwegian Seismic Array (NORSAR) (CCD/411).

On 31 July 1973, the representative of the Netherlands submitted a working paper on an international organ for the support of a chemical weapons convention and other disarmament agreements (CCD/410).

By a letter dated 9 August 1973, the Acting Permanent Representative of Finland transmitted to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament a working paper by the Government of Finland on the progress of the Finnish project for the creation on a national basis of a chemical weapons control capacity for possible future international use (CCD/412).

On 21 August 1973, the representative of Japan submitted a working paper on the main points of an international agreement on the prohibition of the development, production and stockpiling of chemical weapons and their destruction (CCD/413).

On the same date, the representative of Canada submitted a working paper on
the problem of defining chemical substances in a treaty prohibiting the development, production and stockpiling of chemical weapons (CCD/414).

On 23 August 1973, the representative of Mexico submitted a working paper containing a compilation of statements made on the stagnation of the Committee's work, the absence of effective negotiations, and other related matters, at the formal meetings of the Conference of the Committee on Disarmament held from 20 February to 16 August 1973 (585th to 622nd meetings) (CCD/415).

On 28 August 1973, the representative of the Netherlands submitted a working paper containing some observations on the verification of a ban on underground nuclear test explosions (CCD/416).
ANNEX II

Documents of the Conference of the Committee on Disarmament annexed to the report to the General Assembly

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Document No.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Letter dated 11 February 1973 from the Secretary-General of the United Nations to the Co-Chairmen of the Conference of the Committee on Disarmament transmitting the resolutions on disarmament adopted by the General Assembly at its twenty-seventh session</td>
<td>CCD/393</td>
<td>36</td>
</tr>
<tr>
<td>2.</td>
<td>Mexico: letter dated 20 February 1973 from the Leader of the delegation of Mexico to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament</td>
<td>CCD/394</td>
<td>38</td>
</tr>
<tr>
<td>3.</td>
<td>Sweden: working paper on the concept of amplified verification in relation to the prohibition of chemical weapons: the principal role of verification in disarmament treaties</td>
<td>CCD/395</td>
<td>49</td>
</tr>
<tr>
<td>4.</td>
<td>Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia: memorandum</td>
<td>CCD/396</td>
<td>54</td>
</tr>
<tr>
<td>5.</td>
<td>Sweden: working paper with points to be considered by experts on the verification of a ban on underground nuclear explosions</td>
<td>CCD/397</td>
<td>56</td>
</tr>
<tr>
<td>6.</td>
<td>Sweden: working paper presenting the ways in which verification has been dealt with in various arms control and disarmament treaties and proposals</td>
<td>CCD/398</td>
<td>57</td>
</tr>
<tr>
<td>7.</td>
<td>Japan: working paper on problems in determining the body-wave magnitude</td>
<td>CCD/399</td>
<td>60</td>
</tr>
<tr>
<td>8.</td>
<td>Argentina, Brazil, Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia: working paper on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction</td>
<td>CCD/400</td>
<td>71</td>
</tr>
<tr>
<td>9.</td>
<td>United Kingdom: working paper on a review of the United Kingdom seismological research and development programme</td>
<td>CCD/401</td>
<td>75</td>
</tr>
<tr>
<td>10.</td>
<td>United Kingdom: working paper on the estimation of depth of seismic events</td>
<td>CCD/402</td>
<td>83</td>
</tr>
</tbody>
</table>
11. Bulgaria, Czechoslovakia, Hungary, Mongolia, Poland, Romania and Union of Soviet Socialist Republics: working paper on ways of implementing control over compliance with the convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction

12. United States of America: a programme of research related to problems in seismic verification

13. Sweden: working paper reviewing recent Swedish scientific work on the verification of a ban on underground nuclear explosions

14. Canada: the verification of a comprehensive test ban by seismological means

15. United States of America: comments on document CCD/399 concerning magnitude determinations

16. Japan: working paper on a comparison between earthquakes and underground explosions observed at the Matsushiro Seismological Observatory

17. Italy: some observations on detection and identification of underground nuclear explosions - prospects of international co-operation

18. Netherlands: working paper on an international organ for the support of a chemical weapons convention and other disarmament agreements

19. Norway: letter dated 16 July 1973 from the Permanent Representative of Norway to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament transmitting a working paper by the Government of Norway on seismic research at the Norwegian Seismic Array (NORSAR)

20. Finland: letter dated 9 August 1973 from the Acting Permanent Representative of Finland to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament transmitting a working paper by the Government of Finland on the progress of the Finnish project for the creation on a national basis of a chemical weapons control capacity for possible future international use
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Document No.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.</td>
<td>Japan: working paper on the main points of an international agreement on the prohibition of the development, production and stockpiling of chemical weapons and their destruction</td>
<td>CCD/143</td>
<td>199</td>
</tr>
<tr>
<td>22.</td>
<td>Canada: the problem of defining chemical substances in a treaty prohibiting the development, production and stockpiling of chemical weapons</td>
<td>CCD/144</td>
<td>203</td>
</tr>
<tr>
<td>23.</td>
<td>Mexico: working paper containing a compilation of statements made on the stagnation of the Committee's work, the absence of effective negotiations, and other related matters, at the formal meetings of the Conference of the Committee on Disarmament held from 20 February to 16 August 1973 (585th to 622nd meetings)</td>
<td>CCD/145</td>
<td>210</td>
</tr>
<tr>
<td>24.</td>
<td>Netherlands: some observations on the verification of a ban on underground nuclear test explosions</td>
<td>CCD/146</td>
<td>229</td>
</tr>
</tbody>
</table>
Letter dated 11 February 1973 from the Secretary-General of the United Nations to the Co-Chairmen of the Conference of the Committee on Disarmament transmitting the resolutions on disarmament adopted by the General Assembly at its twenty-seventh session (CCD/393)

I have the honour to transmit herewith the following resolutions adopted by the General Assembly at its twenty-seventh session, which entrust specific responsibilities to the Conference of the Committee on Disarmament: resolution 2933 (XXVII), entitled "Chemical and bacteriological (biological) weapons" and resolutions 2934 A, B and C (XXVII), entitled "Urgent need for suspension of nuclear and thermonuclear tests".

In paragraph 2 of resolution 2933 (XXVII), the General Assembly reiterates its request, made to the Conference of the Committee on Disarmament in resolution 2827 A (XXVI), to continue negotiations, as a matter of high priority, with a view to reaching early agreement on effective measures for the prohibition of the development, production and stockpiling of chemical weapons and for their destruction; paragraph 3 stresses the importance of working towards the complete realization of the objective of effective prohibition of chemical weapons as set forth in the resolution and urges Governments to work towards that end; and paragraph 7 requests the Conference of the Committee on Disarmament to report on the results of its negotiations to the General Assembly at its twenty-eighth session.

In paragraph 3 of section II of resolution 2934 A (XXVII), the General Assembly calls upon the Conference of the Committee on Disarmament to give urgent consideration to the question of a treaty banning all nuclear weapon tests, taking into account the views already expressed in the Conference, the opinions stated at the twenty-seventh session of the General Assembly and, above all, the pressing need for the early conclusion of such a treaty.

In paragraph 4 of resolution 2934 B (XXVII), the General Assembly urges Governments that have been carrying out nuclear weapon tests to take an active and constructive part in presenting and developing in the Conference of the Committee on Disarmament, or in any other appropriate body, specific proposals for a comprehensive test ban; in paragraph 5, it requests the Conference of the Committee on Disarmament to give first priority to its deliberations on a treaty banning underground nuclear weapon tests, taking full account of views of experts and of technical developments bearing on the verification of such a treaty, and further requests the Conference to submit a special report to the General Assembly at its twenty-eighth session on the results of its deliberations on this matter.

In paragraph 2 of resolution 2934 C (XXVII), the General Assembly reaffirms its conviction that, whatever may be the differences on the question of verification, there is no valid reason for delaying the conclusion of a comprehensive test ban of the nature contemplated in the preamble to the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water; in paragraph 3, the Assembly urges once more the Governments of nuclear-weapon
States to bring to a halt all nuclear weapon tests at the earliest possible date, and in any case not later than 5 August 1973, either through a permanent agreement or through unilateral or agreed moratoria.

In paragraph 6 of resolution 2933 (XXVII), the General Assembly requested the Secretary-General to transmit to the Conference of the Committee on Disarmament all documents of the First Committee relating to questions connected with the problem of chemical weapons and chemical methods of warfare. The relevant documents and records are the following: A/C.1/L.628; A/C.1/PV.1872-1890, 1897 and 1898; A/8905; 1/ A/PV.2093. These documents and records were distributed during the twenty-seventh session of the General Assembly to all Members of the United Nations, including all the members of the Conference.

I also have the honour to transmit herewith, for the information of the members of the Conference, the following resolutions adopted by the General Assembly, at its twenty-seventh session, which deal with disarmament matters: 2/ resolution 2930 (XXVII), entitled "World Disarmament Conference"; resolution 2931 (XXVII), entitled "Implementation of the results of the Conference of Non-Nuclear-Weapon States"; resolutions 2932 A and B (XXVII), entitled "General and complete disarmament"; resolution 2935 (XXVII), entitled "Implementation of General Assembly resolution 2830 (XXVI) concerning the signature and ratification of Additional Protocol II of the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco)"; resolution 2936 (XXVII), entitled "Non-use of force in international relations and permanent prohibition of the use of nuclear weapons"; resolution 2992 (XXVII), entitled "Declaration of the Indian Ocean as a zone of peace".

I also wish to refer, for your information, to General Assembly resolutions 2993 (XXVII) and 3032 (XXVII). In resolution 2993 (XXVII), entitled "Implementation of the Declaration on the Strengthening of International Security", paragraph 5, the General Assembly believed that the co-ordinated consideration of related issues, inter alia, disarmament, peace-keeping and strengthening of the role of the United Nations, would to a large extent enhance the political and diplomatic effectiveness of the United Nations, including the work of the General Assembly, thus facilitating action towards the strengthening of international security. In resolution 3032 (XXVII), entitled "Respect for human rights in armed conflicts", paragraph 4, the Secretary-General was requested to report to the General Assembly at its twenty-eighth session on relevant developments concerning human rights in armed conflicts and to prepare, as soon as possible, a survey of existing rules of international law concerning the prohibition or restriction of use of specific weapons.

(Signed) Kurt WALDHEIM
Secretary-General

1/ See Official Records of the General Assembly, Twenty-seventh Session, Annexes, agenda items 26, 27, 30, 31, 32, 33 and 34.

2. MEXICO

Letter dated 20 February 1973 from the Leader of the delegation of Mexico to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament (CCD/39)

Original: English/Spanish
20 February 1973

My delegation considers that the contents of General Assembly document A/C.1/1026 of 3 November 1972 are of direct interest to the Conference of the Committee on Disarmament. I therefore request you to be so kind as to have it reproduced as a Conference document.

(Signed) Alfonso GARCIA ROBLES
Leader of the delegation of Mexico to the Conference of the Committee on Disarmament

Letter dated 3 November 1972 from the Chairman of the delegation of Mexico to the twenty-seventh session of the General Assembly addressed to the Secretary-General

Original: Spanish

In view of the launching of negotiations between the Governments of the United States of America and the Union of Soviet Socialist Republics on the limitation of offensive and defensive strategic nuclear-weapon systems, the General Assembly, on 16 December 1969, adopted resolution 2602 A (XXIV), the last paragraph of which is worded as follows:

"Appeals to the Governments of the Union of Soviet Socialist Republics and the United States of America to agree, as an urgent preliminary measure, on a moratorium on further testing and deployment of new offensive and defensive strategic nuclear-weapon systems."

Subsequently, during the twenty-fifth session, the Assembly recommended, in resolution 2661 C (XXV), that the comprehensive programme of disarmament reproduced in document A/8191 3/ should be taken into account in future work and negotiations on disarmament.

Lastly, it should be remembered that the comprehensive programme of disarmament draws attention in its introduction to the need to establish effective procedures to ensure that the General Assembly be kept informed on the progress of "all negotiations and other acts on this matter, in whatever forum and form they may take place".

Taking into consideration the facts summarized above, as well as the frequent references made during the discussions in the First Committee to the results of the bilateral negotiations carried out between the United States of America and the Union of Soviet Socialist Republics, which are generally referred to as the Strategic Arms Limitation Talks (SALT I), the Mexican delegation feels that it is highly advisable for the General Assembly to include among its documents the official texts of the three instruments signed in Moscow, on 26 May 1972, by the aforementioned States.

It was for that reason that, on 23 October last, when the debate on the disarmament items began in the First Committee, after referring to the SALT I negotiations, I added that "we believe the Assembly has a right to be officially informed of their results, at the present session, by the participating States" (see A/C.1/PV.1872).

This is why, since that statement has not had the desired effect, I would request you to circulate the three bilateral instruments, whose titles are given below, as a General Assembly document under item 30 of the agenda for the twenty-seventh session. I have the honour to enclose with this note the texts of the instruments as reproduced in the relevant official publication of the Government of the United States of America:

(a) Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems;

(b) Interim Agreement between the United States of America and the Union of Soviet Socialist Republics on Certain Measures with Respect to the Limitation of Strategic Offensive Arms;

(c) Protocol to the Interim Agreement between the United States of America and the Union of Soviet Socialist Republics on Certain Measures with Respect to the Limitation of Strategic Offensive Arms.

(Signed) Alfonso GARCIA ROBLES
Chairman of the delegation of Mexico to the twenty-seventh session of the United Nations General Assembly

-39-
A. TREATY BETWEEN THE UNITED STATES OF AMERICA AND
THE UNION OF SOVIET SOCIALIST REPUBLICS ON THE
LIMITATION OF ANTI-BALLISTIC MISSILE SYSTEMS

The United States of America and the Union of Soviet Socialist Republics,
hereinafter referred to as the Parties,

Proceeding from the premise that nuclear war would have devastating
consequences for all mankind,

Considering that effective measures to limit anti-ballistic missile systems,
would be a substantial factor in curbing the race in strategic offensive arms and
would lead to a decrease in the risk of outbreak of war involving nuclear weapons,

Proceeding from the premise that the limitation of anti-ballistic missile
systems, as well as certain agreed measures with respect to the limitation of
strategic offensive arms, would contribute to the creation of more favourable
conditions for further negotiations on limiting strategic arms,

Mindful of their obligations under article VI of the Treaty on the
Non-Proliferation of Nuclear Weapons,

Declaring their intention to achieve at the earliest possible date the
cessation of the nuclear arms race and to take effective measures towards
reductions in strategic arms, nuclear disarmament, and general and complete
disarmament,

Desiring to contribute to the relaxation of international tension and the
strengthening of trust between States,

Have agreed as follows:

ARTICLE I

1. Each Party undertakes to limit anti-ballistic missile (ABM) systems and
to adopt other measures in accordance with the provisions of this Treaty.

2. Each Party undertakes not to deploy ABM systems for a defense of the
territory of its country and not to provide a base for such a defense, and not to
deploy ABM systems for defense of an individual region except as provided for in
article III of this Treaty.

ARTICLE II

1. For the purposes of this Treaty, an ABM system is a system to counter
strategic ballistic missiles or their elements in flight trajectory, currently
consisting of:

-40-
(a) ABM interceptor missiles, which are interceptor missiles constructed and deployed for an ABM role, or of a type tested in an ABM mode;

(b) ABM launchers, which are launchers constructed and deployed for launching ABM interceptor missiles; and

(c) ABM radars, which are radars constructed and deployed for an ABM role, or of a type tested in an ABM mode.

2. The ABM system components listed in paragraph 1 of this article include those which are:

(a) Operational;

(b) Under construction;

(c) Undergoing testing;

(d) Undergoing overhaul, repair or conversion; or

(e) Mothballed.

ARTICLE III

Each Party undertakes not to deploy ABM systems or their components except that:

(a) Within one ABM system deployment area having a radius of 150 kilometers and centered on the Party's national capital, a Party may deploy: (1) no more than 100 ABM launchers and no more than 100 ABM interceptor missiles at launch sites, and (2) ABM radars within no more than six ABM radar complexes, the area of each complex being circular and having a diameter of no more than three kilometers; and

(b) Within one ABM system deployment area having a radius of 150 kilometers and containing ICBM silo launchers, a Party may deploy: (1) no more than 100 ABM launchers and no more than 100 ABM interceptor missiles at launch sites, (2) two large phased-array ABM radars comparable in potential to corresponding ABM radars operational or under construction on the date of signature of the Treaty in an ABM system deployment area containing ICBM silo launchers, and (3) no more than 18 ABM radars, each having a potential less than the potential of the smaller of the above-mentioned two large phased-array ABM radars.

ARTICLE IV

The limitations provided for in article III shall not apply to ABM systems or their components used for development or testing, and located within current or additionally agreed test ranges. Each Party may have no more than a total of 15 ABM launchers at test ranges.
ARTICLE V

1. Each Party undertakes not to develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based or mobile land-based.

2. Each Party undertakes not to develop, test, or deploy ABM launchers for launching more than one ABM interceptor missile at a time from each launcher, nor to modify deployed launchers to provide them with such a capability, nor to develop, test, or deploy automatic or semi-automatic or other similar systems for rapid reload of ABM launchers.

ARTICLE VI

To enhance assurance of the effectiveness of the limitations on ABM systems and their components provided by this Treaty, each Party undertakes:

(a) Not to give missiles, launchers, or radars, other than ABM interceptor missiles, ABM launchers, or ABM radars, capabilities to counter strategic ballistic missiles or their elements in flight trajectory, and not to test them in an ABM mode; and

(b) Not to deploy in the future radars for early warning of strategic ballistic missile attack except at locations along the periphery of its national territory and oriented outward.

ARTICLE VII

Subject to the provisions of this Treaty, modernization and replacement of ABM systems or their components may be carried out.

ARTICLE VIII

ABM systems or their components in excess of the numbers or outside the areas specified in this Treaty, as well as ABM systems or their components prohibited by this Treaty, shall be destroyed or dismantled under agreed procedures within the shortest possible agreed period of time.

ARTICLE IX

To assure the viability and effectiveness of this Treaty, each Party undertakes not to transfer to other States, and not to deploy outside its national territory, ABM systems or their components limited by this Treaty.

ARTICLE X

Each Party undertakes not to assume any international obligations which would conflict with this Treaty.
ARTICLE XI

The Parties undertake to continue active negotiations for limitations on strategic offensive arms.

ARTICLE XII

1. For the purpose of providing assurance of compliance with the provisions of this Treaty, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.

2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this article.

3. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this Treaty. This obligation shall not require changes in current construction, assembly, conversion or overhaul practices.

ARTICLE XIII

1. To promote the objectives and implementation of the provisions of this Treaty, the Parties shall establish promptly a Standing Consultative Commission, within the framework of which they will:

(a) Consider questions concerning compliance with the obligations assumed and related situations which may be considered ambiguous;

(b) Provide on a voluntary basis such information as either Party considers necessary to assure confidence in compliance with the obligations assumed;

(c) Consider questions involving unintended interference with national technical means of verification;

(d) Consider possible changes in the strategic situation which have a bearing on the provisions of this Treaty;

(e) Agree upon procedures and dates for destruction or dismantling of ABM systems or their components in cases provided for by the provisions of this Treaty;

(f) Consider, as appropriate, possible proposals for further increasing the viability of this Treaty, including proposals for amendments in accordance with the provisions of this Treaty;

(g) Consider, as appropriate, proposals for further measures aimed at limiting strategic arms.

2. The Parties through consultation shall establish, and may amend as appropriate, Regulations for the Standing Consultative Commission governing procedures, composition and other relevant matters.
ARTICLE XIV

1. Each Party may propose amendments to this Treaty. Agreed amendments shall enter into force in accordance with the procedures governing the entry into force of this Treaty.

2. Five years after entry into force of this Treaty, and at five-year intervals thereafter, the Parties shall together conduct a review of this Treaty.

ARTICLE XV

1. This Treaty shall be of unlimited duration.

2. Each Party shall, in exercising its national sovereignty, have the right to withdraw from this Treaty if it decides that extraordinary events related to the subject-matter of this Treaty have jeopardized its supreme interests. It shall give notice of its decision to the other Party six months prior to withdrawal from the Treaty. Such notice shall include a statement of the extraordinary events the notifying Party regards as having jeopardized its supreme interests.

ARTICLE XVI

1. This Treaty shall be subject to ratification in accordance with the constitutional procedures of each Party. The Treaty shall enter into force on the day of the exchange of instruments of ratification.

2. This Treaty shall be registered pursuant to Article 102 of the Charter of the United Nations.

DONE at Moscow on 26 May 1972, in two copies, each in the English and Russian languages, both texts being equally authentic.

For the United States of America:

Richard NIXON
President of the United States of America

For the Union of Soviet Socialist Republics:

L. I. BREZHNEV
General Secretary of the Central Committee of the CPSU
B. INTERIM AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND
THE UNION OF SOVIET SOCIALIST REPUBLICS ON CERTAIN MEASURES
WITH RESPECT TO THE LIMITATION OF STRATEGIC OFFENSIVE ARMS

The United States of America and the Union of Soviet Socialist Republics, hereinafter referred to as the Parties,

Convinced that the Treaty on the Limitation of Anti-Ballistic Missile Systems and this Interim Agreement on Certain Measures with Respect to the Limitation of Strategic Offensive Arms will contribute to the creation of more favorable conditions for active negotiations on limiting strategic arms as well as to the relaxation of international tension and the strengthening of trust between States,

Taking into account the relationship between strategic offensive and defensive arms,

Mindful of their obligations under article VI of the Treaty on the Non-Proliferation of Nuclear Weapons,

Have agreed as follows:

ARTICLE I

The Parties undertake not to start construction of additional fixed land-based intercontinental ballistic missile (ICBM) launchers after 1 July 1972.

ARTICLE II

The Parties undertake not to convert land-based launchers for light ICBMs, or for ICBMs of older types deployed prior to 1964, into land-based launchers for heavy ICBMs of types deployed after that time.

ARTICLE III

The Parties undertake to limit submarine-launched ballistic missile (SLBM) launchers and modern ballistic missile submarines to the numbers operational and under construction on the date of signature of this Interim Agreement, and in addition to launchers and submarines constructed under procedures established by the Parties as replacements for an equal number of ICBM launchers of older types deployed prior to 1964 or for launchers on older submarines.

ARTICLE IV

Subject to the provisions of this Interim Agreement, modernization and replacement of strategic offensive ballistic missiles and launchers covered by this Interim Agreement may be undertaken.
ARTICLE V

1. For the purpose of providing assurance of compliance with the provisions of this Interim Agreement, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.

2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this article.

3. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this Interim Agreement. This obligation shall not require changes in current construction, assembly, conversion, or overhaul practices.

ARTICLE VI

To promote the objectives and implementation of the provisions of this Interim Agreement, the Parties shall use the Standing Consultative Commission established under article XIII of the Treaty on the Limitation of Anti-Ballistic Missile Systems in accordance with the provisions of that article.

ARTICLE VII

The Parties undertake to continue active negotiations for limitations on strategic offensive arms. The obligations provided for in this Interim Agreement shall not prejudice the scope or terms of the limitations on strategic offensive arms which may be worked out in the course of further negotiations.

ARTICLE VIII

1. This Interim Agreement shall enter into force upon exchange of written notices of acceptance by each Party, which exchange shall take place simultaneously with the exchange of instruments of ratification of the Treaty on the Limitation of Anti-Ballistic Missile Systems.

2. This Interim Agreement shall remain in force for a period of five years unless replaced earlier by an agreement on more complete measures limiting strategic offensive arms. It is the objective of the Parties to conduct active follow-on negotiations with the aim of concluding such an agreement as soon as possible.

3. Each Party shall, in exercising its national sovereignty, have the right to withdraw from this Interim Agreement if it decides that extraordinary events related to the subject-matter of this Interim Agreement have jeopardized its supreme interests. It shall give notice of its decision to the other Party six months prior to withdrawal from this Interim Agreement. Such notice shall include a statement of the extraordinary events the notifying Party regards as having jeopardized its supreme interests.
DONE at Moscow on 26 May 1972, in two copies, each in the English and Russian languages, both texts being equally authentic.

For the United States of America:

Richard NIXON
President of the United States of America

For the Union of Soviet Socialist Republics:

L. I. BREZHNEV
General Secretary of the Central Committee of the CPSU

C. PROTOCOL TO THE INTERIM AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNION OF SOVIET SOCIALIST REPUBLICS ON CERTAIN MEASURES WITH RESPECT TO THE LIMITATION OF STRATEGIC OFFENSIVE ARMS

The United States of America and the Union of Soviet Socialist Republics, hereinafter referred to as the Parties,

Having agreed on certain limitations relating to submarine-launched ballistic missile launchers and modern ballistic missile submarines, and to replacement procedures, in the Interim Agreement,

Have agreed as follows:

The Parties understand that, under article III of the Interim Agreement, for the period during which that Agreement remains in force:

The United States may have no more than 710 ballistic missile launchers on submarines (SLBMs) and no more than 64 modern ballistic missile submarines. The Soviet Union may have no more than 950 ballistic missile launchers on submarines and no more than 62 modern ballistic missile submarines.

Additional ballistic missile launchers on submarines up to the above-mentioned levels, in the United States - over 65 ballistic missile launchers on nuclear-powered submarines, and in the Union of Soviet Socialist Republics - over 740 ballistic missile launchers on nuclear-powered submarines, operational and under construction, may become operational as replacements for equal numbers of ballistic missile launchers of older types deployed prior to 1964 or of ballistic missile launchers on older submarines.

The deployment of modern SLBMs on any submarine, regardless of type, will be counted against the total level of SLBMs permitted for the United States and the Union of Soviet Socialist Republics.
This Protocol shall be considered an integral part of the Interim Agreement.

DONE at Moscow this twenty-sixth day of May 1972.

For the United States of America:

Richard NIXON
President of the United States of America

For the Union of Soviet Socialist Republics:

L. I. BREZHNEV
General Secretary of the Central Committee of the CPSU
The principal role of verification in disarmament treaties (CCD/395)

The use of control methods is stipulated in a treaty in order to verify that the parties comply with their undertakings under that treaty. General models for different types of control can be worked out. However, the conditions in the field to be covered by a treaty determine the actual verification measures to be stipulated. This can be exemplified briefly: with regard to the comprehensive test ban, only one control measure (detection of underground explosions) is discussed; with regard to nuclear material, control of the production of only one substance (down to kilogram quantities) by means of several methods is discussed. In contrast, a possible treaty prohibiting the development, production and stockpiling of chemical agents of warfare will have to employ several control methods, covering not only several activities, but also (tons of) many different chemical substances. This fact implies not only that usual decision theories are not easily applicable, but also that the question of false alarms must be given special attention. A discussion of these two aspects is attempted in the following paragraphs. Practical and political implications are considered.

The role of verification in a ban on development, production and stockpiling of chemical agents of warfare

A chemical development, production and stockpiling ban covering several chemical agents will require several different control methods. This has become quite clear from the discussions in the Conference of the Committee on Disarmament.

It has been argued, although no consensus has been reached so far, that the primary purpose of the many possible control methods in a future chemical ban should be to trigger some kind of procedure to establish whether a violation of the treaty has occurred or not. Furthermore, no agreement has been reached whether this procedure should involve on-site inspection or be restricted to some less intrusive procedure. This part of the verification process will not be discussed in this paper. It is, however, assumed that the control methods discussed in the following are to be managed by an international control organization, using e.g. nationally gathered information for the purpose of control, as may be agreed upon in a treaty.

The necessity of using many control methods and the uncertainty as to the form for establishing a treaty violation makes it insufficient to consider the kind of discriminatory decision levels generated by a single verification measure which would apply in the case of the comprehensive test ban. Instead, it will be necessary to consider the effects of several verification measures in combination; in other words, to evaluate the amplified verification described later in this paper.
Amplification of verification efficiency

Much discussion has been devoted to how effective a non-intrusive method for the verification of the compliance with a disarmament treaty should be in order to deter its parties from violating the treaty, when subsequent on-site inspection is allowed or not, as the case may be. There seems to be consensus that the verification methods need in no case be 100 per cent effective.

Less attention seems to have been focused on the consequences of using several independent methods of verification, each with limited prospects of success, in revealing a violation. This is commented upon below, with special reference to the attempts to agree upon a ban on the development, production and stockpiling of chemical agents of warfare.

It is intuitively felt that the use of several independent methods of verification should increase the possibility of detecting treaty violations. Such an increase can easily be shown formally by applying a simple mathematical reasoning about probabilities. 4/

To illustrate the effect of the amplification of the verification, one may consider the hypothetical situation concerning a ban on the development, production and stockpiling of chemical warfare agents given below. The revealing probabilities given in the example may be too high to be realistic, but then more methods can be introduced under the headings given. In a real case, the given "revealing probabilities" should be evaluated by relevant experts, as discussed below.

Elements contained in an assumed prohibition of chemical arms and hypothetical verification results of their application

<table>
<thead>
<tr>
<th>Forbidden activity</th>
<th>Possible verification method</th>
<th>Hypothetical values of revealing probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research on supertoxic substances, antidotes</td>
<td>Scanning literature by computer</td>
<td>0.03</td>
</tr>
<tr>
<td>Field tests</td>
<td>Remote sensing from satellites</td>
<td>0.1 a/</td>
</tr>
<tr>
<td>Production</td>
<td>Statistical survey of export-import data for basic chemicals, e.g. Phosphorus</td>
<td>0.03</td>
</tr>
<tr>
<td>Stockpiling</td>
<td>Finding instructions for handling of chemical munition</td>
<td>0.03</td>
</tr>
<tr>
<td>Training</td>
<td>Finding manuals on offensive use of chemical munition</td>
<td>0.01</td>
</tr>
</tbody>
</table>


False alarms

Evidently, the political drawbacks of a false alarm due to the performance of a control method are serious. That a nation, because of imperfect technical means, can be falsely accused of violating a treaty may to some parties be more objectionable than being left with a verification method that cannot detect every violation committed by other parties. It is thus important that the verification results be presented in a way that cannot be interpreted as an accusation. To achieve this is one of the aims of the verification model discussed in the present paper.

It is assumed that the function of the accumulating circumstantial evidence from the several verification methods will be to trigger such further investigatory procedures as may be agreed upon in a treaty. One could then foresee that requests for complementary information to back up quite normal findings about toxicological work, pesticide production etc., obtained by the verification methods, would be considered as a normal routine procedure. Such a procedure would probably also make it easier to secure co-operation with industries.
The way of circumventing the problem of false alarms would lie in the insight and acceptance of the fact that each verification method is in itself a weak instrument, which only in exceptional cases can give a straight answer and which normally provides incomplete answers. Thus, there should be no reason to look upon a single result as an alarm, but rather as part of the continuous information procedure.

Need to give alarm alleging that a party has violated a treaty will arise only when several or all verification methods concur to indicate the possibility of a treaty violation, when requests made by routine for complementary information are rejected without reason, or when the information given turns out to be inconsistent with other information obtained.

The remaining genuine uncertainty

It might be questioned whether the application of the "amplified verification" system has a reassuring rather than a deterring effect on a party to the treaty. This may be described in the following way:

When two potentially adverse parties adhere to a treaty prohibiting production of chemical warfare agents, this implies that both parties officially wish to uphold the treaty. Being signatories of the treaty, neither wishes to be exposed as violating the treaty ban. At the same time, neither can accept that the other party could secretly violate the treaty. Thus the primary need is to have a verification system sufficiently reliable to expose to some degree an adverse violator. If one of the parties feels reassured about these possibilities, he can abstain from a capability of waging chemical war himself for any of three reasons: (i) he does not wish to have such a capability; (ii) he would not need it, since an adversary can be expected to be disclosed at an acceptable level of probability (provided, as is done here, that this gives him time to take countermeasures); (iii) he would himself suffer the same risk as the adversary of being exposed by the verification system. From this reasoning, it can be inferred that the reassuring effect would come first and thus in itself be sufficient.

The situation would essentially be the same if one or both of the parties already possessed a war-waging capability with chemical agents before becoming parties to the treaty. A treaty prescribing destruction of stockpiles would require verification methods for this, as well as for other activities covered by the treaty. Thus, by definition, the verification effect would be amplified again by introducing another control activity.

Thus, if it is possible to construct a reasonably reassuring control system, the problem would revert to the genuine uncertainty of whether some other power - perhaps a potential adversary - intends in the future to acquire a chemical war capability. It can be assumed that any party entering into a treaty would expect other parties to observe the treaty obligations. The genuine uncertainty referred to above would therefore only relate to a more distant future. To assess this remains a political task, where one would have to take into account the option offered by the withdrawal clause in the treaty.
Practical and political implications

It may be interesting not only to determine how successful a verification method may be in disclosing a forbidden activity, which is, in effect, not likely to occur. As suggested above, one could, for example, also introduce a concept implying that a verification method investigates some normally occurring activity which is likely to undergo some change if and when a violation of the treaty is being prepared or is already taking place. The control method could be designed to analyse certain relevant data. The efficiency might be expressed through the confidence which experts would have in the verification method as to its ability to perform its task.

Politically, this means that it would be difficult for a country to start an activity in the field of chemical warfare which could go on totally unnoticed; warning signs would be obtained, even if they might be explained away.

Should several warnings appear simultaneously, they should certainly, taken together, be sufficient to warrant an investigation, if such a procedure is provided for in the treaty, or to entitle any party to withdraw from the treaty. Since the result of the verification methods would be official and would be known by all parties, it would be easy for all other parties to judge the fairness of a withdrawal.

This procedure should therefore be easier to apply in the event that a suspected violator was unwilling to explain the coincidence of several "warning signs" or vetoed an investigation.

A withdrawal clause similar to the one just discussed hypothetically is found in the first development, production and stockpiling ban on biological and chemical agents of warfare, the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction.

Conclusions

The over-all efficiency of the verification system of a treaty prohibiting the development, production and stockpiling of chemical agents is increased by the use of several verification methods. The verification methods may not be exclusively aimed at detecting violations, but could primarily be designed to detect, with known efficiency, changes in normal activities in the chemical field. Such changes might constitute warning signs. The occurrence of many warning signs on behalf of a party to the treaty, in connexion with unwillingness to explain them or to let an investigation take place, might enable other parties to withdraw from the treaty. This construction of the verification system makes it reassuring rather than deterring. In view of the fact that the use of chemical warfare agents is already forbidden by the Geneva Protocol of 1925, such a reassurance should be sufficient.
Memorandum

The delegations of Burma, Egypt, Ethiopia, Mexico, Nigeria, Sweden and Yugoslavia deem it appropriate, at the outset of the twelfth year of the existence of the Conference of the Committee on Disarmament, to state the following.

1. They consider that the Conference of the Committee on Disarmament, which is the main multilateral negotiating body for disarmament, is of fundamental importance to the United Nations and the world community.

2. They also consider that the present international political situation is favourable for achieving further concrete results in the field of disarmament measures, adhering to the priorities established in the provisional agenda of the Committee and the relevant resolutions of the United Nations General Assembly.

3. Conscious of the responsibilities of the Conference of the Committee on Disarmament to mankind and to the United Nations, they are increasingly concerned by the lack of tangible progress in the solution of the main disarmament problems entrusted to the Committee — a situation which became apparent during its last session and which the meetings of the present session have so far confirmed.

4. While stressing that it is the duty of all members of the Conference of the Committee on Disarmament to contribute positively to the work of the Committee, it is their firm belief that primary responsibility rests with the two States which have been exercising jointly the chairmanship of the Committee and which also possess, to an overwhelmingly greater degree, nuclear weapons and other weapons of mass destruction.

5. While reiterating their view that it is most desirable that all nuclear-weapons States participate in the disarmament negotiations, they also reaffirm their opinion that the non-participation of two of those States in the work of the Conference of the Committee on Disarmament should not prevent the Committee from discharging its obligations.

6. It is their conviction that there is no reason which may justify any stagnation of the Committee's work and the current absence of effective negotiations, especially in the case of the following two questions, concerning which the General Assembly has repeatedly requested the Committee to deal with as matters of "first" or "high" priority:

(a) Cessation of all nuclear weapon tests, in conformity with the preamble to the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water; and
(b) Effective prohibition of the development, production and stockpiling of chemical weapons and the elimination of such weapons from military arsenals of all States, as agreed upon in article IX of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction.

Negotiations in the current phase of the work of the Committee should, therefore, concentrate on the most important questions related to nuclear and other weapons of mass destruction and not on less pressing matters.

7. In the light of the preceding considerations, they believe that it is the duty of all States members of the Conference of the Committee on Disarmament to contribute positively to the progress of the work of the Committee and urge the two States referred to in paragraph 4 above to take the required decisions and necessary measures, including the submission of specific proposals, in order that both the relevant resolutions of the General Assembly and the solemn undertakings assumed in the preamble of the partial test ban treaty and in article IX of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction may begin to receive effective implementation.
1. Methods and present capabilities for verification
   (a) Seismological methods, single or in combination;
   (b) Seismological capabilities and limitations;
   (c) Other methods for verification, including those using observation from satellites;
   (d) Capabilities and limitations of other methods, including those using observations from satellites.

2. Verification aspects of proposed treaty structures
   (a) Limitation to national means and international data exchange;
   (b) Technical significance of obligatory on-site inspections;
   (c) Verification upon request and on-site inspection by invitation;
   (d) Limitations to the numbers and strengths of nuclear explosions, including fixed or moving thresholds and phase-outs;
   (e) Moratoria.

3. Technical and organizational matters to be settled in connexion with a ban on underground nuclear explosions
   (a) Improvements of seismometric networks and stations;
   (b) Seismometric data processing, data transmission and data exchange;
   (c) Similar aspects of other methods, including those using observations from satellites;
   (d) International co-operation and organization for verification of a ban on underground nuclear explosions. The connexion with other international measures of disarmament and arms control. International disarmament organization.

4. General statements and other matters
6. SWEDEN

Working paper presenting the ways in which verification has been
dealt with in various arms control and disarmament treaties and
proposals (CCD/398)

[Original: English]
[24 April 1973]

In document CCD/2&7, 5/ dated 30 April 1970, the Swedish delegation presented
some material indicating how the question of verification of collateral arms
regulation or disarmament measures had been dealt with in the recent past in agreed
treaties and in some of the proposals which had been presented, mainly in the
Conference of the Committee on Disarmament or in the Conference of the
Eighteen-Nation Committee on Disarmament.

The findings were illustrated by a table. As two new international treaties
have been negotiated in the Conference of the Committee on Disarmament since
April 1970, a revised form of the table, also including those treaties, is presented
in the appendix below. The two drafts on general and complete disarmament
presented in 1962 by the Soviet Union and the United States have also been included
in the new table.

The following treaties and proposals have been chosen:

(a) Treaties

1. The Antarctic Treaty, of 1959; 6/

2. Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and
under Water, of 1963; 7/

3. Treaty on Principles Governing the Activities of States in the Exploration and
Use of Outer Space, including the Moon and other Celestial Bodies, of 1967; 8/

4. Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of
Tlatelolco), of 1967; 9/

5. Treaty on the Non-Proliferation of Nuclear Weapons, of 1968, with the safeguards
system of the International Atomic Energy Agency; 10/

document DC/233, annex C.

7/ Ibid., vol. 480, No. 6964.
8/ General Assembly resolution 2222 (XXI), annex.
10/ General Assembly resolution 2373 (XXII), annex.

7. Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, of 1972. 12/

(b) Proposals

8. Agreed parts of the draft treaty on the discontinuance of nuclear weapon tests, of 1959; 13/

9. Union of Soviet Socialist Republics, Draft treaty on general and complete disarmament under strict international control, 1962 (ENDC/2); 14/

10. United States of America: outline of basic provisions of a treaty on general and complete disarmament in a peaceful world, 1962 (ENDC/30); 15/

11. Poland: memorandum concerning the establishment of a denuclearized and limited armaments zone in Europe, 1962 (ENDC/C.1/1) and memorandum on freezing nuclear and thermonuclear weapons in Central Europe, 1964; 16/


11/ General Assembly resolution 2660 (XXV), annex.
12/ General Assembly resolution 2826 (XXVI), annex.
### APPENDIX

**Verification system:**

<table>
<thead>
<tr>
<th>1. Collection of information</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obligatory declaration and notification</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ground, naval and air observation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Special detection and identification techniques</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>International exchange of reports or data</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Inquiry</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. On-site inspection by parties</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obligatory continuing, periodic or in a limited number</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>On the basis of free access</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>On the basis of consultation, co-operation or invitation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. International supervision and inspection</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specially established control organization</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Existing organization</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Investigation by the United Nations Secretary-General</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. National self-supervision and inspection</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Complaint procedure</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultation and co-operation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Preference to a conference of the parties</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Preference to the International Court of Justice</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Recourse to the United Nations Security Council</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Review of verification system</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
7. JAPAN

Working paper on problems in determining the body-wave magnitude
(CCD/399)

[Original: English]
[24 April 1973]

1. Present importance of body-wave magnitude mb
in the comprehensive test ban issue

United Kingdom working paper CCD/363/Rev.1 18/ gave a pertinent summary on
seismic magnitudes with special reference to the comprehensive test ban discussion.
As described there, we have used from the beginning in comprehensive test ban
issues seismic magnitude in terms of mb, body-wave magnitude determined by
short-period vertical component seismometers almost exclusively. Only recently has
the adequacy of applying Ms instead of mb been pointed out and Ms is recommended
as representing the equivalent yield better than mb in the Swedish, Canadian and
United Kingdom working papers (CCD/306, 19/ CCD/327 and Add.1 20/ and
CCD/363/Rev.1).

However, it must be noted that the above results have been mainly obtained on
a research basis and the seismological routine service determines Ms only for a
several per cent of all detected seismic events of the globe, but mb for almost all
of them. The detection capabilities of the present routine network for surface
waves is presently much lower than that for P waves, although the deployment of a
high-gain-long-period seismograph network will be able to improve the level. As in
a comprehensive test ban the detection and identification of small-size events are
important, we cannot at least for the moment switch over from mb to Ms to represent
the size. Moreover a sudden employment of Ms in place of mb will also confuse
people who have been accustomed to using the mb scale for a long time in the
comprehensive test ban issues and it may be premature to switch over from mb to
Ms. Also, considering the importance of discrimination by mb:Ms method and some
promising short-period discriminants, we cannot live without mb. Thus, we should
try to obtain the indisputable agreed value of mb for all events in our routine
monitoring system for a comprehensive test ban.

18/ Ibid., Supplement for 1972, document DC/235, annex B.
19/ Ibid., Supplement for 1970, document DC/233, annex C.
20/ Ibid., Supplement for 1971, document DC/234, annex C.
2. Fluctuation of body-wave magnitude

In CCD/363/Rev.1 the anomalous values of mb at Eskdalemuir Array in Scotland (EKA) for the two United States nuclear explosions, Gasbuggy and Rulison, relative to their yield in kilotons are described. Namely, mb at EKA is 5.4 for 26 kT Gasbuggy, while mb at EKA for 40 kT Rulison is only 4.7. Document CCD/363/Rev.1 gave teleseismic average values of mb for Gasbuggy and Rulison as 5.0 and 4.9 respectively, with less discrepancy in the yields. The Bulletin of the International Seismological Centre gives mb 4.8 on 14 observations for Gasbuggy and mb 5.0 on 17 observations for Rulison. The relation between yield and mb looks more reasonable. Another example showing more anomalous relations between yield and mb in CCD/363/Rev.1 are large Soviet chemical explosions Medeo (1) and (2), 1.7 and 3.6 kilotons giving mb 5.0 and 5.2 at EKA, respectively. The mb values are too large compared with that of Rulison and Gasbuggy.

It is commonly thought that, although mb at individual stations differs from station to station, their average gives a stable mb with standard deviation less than 1/4 if we take mb at more than 20 to 30 stations. An individual station mb would very probably show inevitable fluctuations and cannot be considered as a reliable measure of the size of events. If one party uses the mean value of mb obtained at a few arbitrary stations, it is very probable that other parties would not agree about the value and consequently any conclusion derived by using that particular mb could not be accepted. In the following section an example of such a disagreement will be given.

3. On Tibet-Assam explosion-like seismic events with special reference to their mb values

United States working paper CCD/388 was very important and instructive for our comprehensive test ban issues. It has a constructive side in reviewing recent technical accomplishments which give us hopes of detecting and identifying teleseismic events down to mb 4.0, while in 1960 we considered mb 4.75 a remote target. The several remaining problems mentioned are, of course, all very important and in particular it is to be welcomed that the paper pointed out explicitly the problem of anomalous events, showing concrete examples, which had often been mentioned vaguely against the optimistic opinion on discrimination. For the problems of mixed events and of the rate of doubtful events in the USSR, it is hoped to give a concrete presentation as for the Tibet-Assam anomalous events which will make possible follow-up examinations and further studies by other parties.

As noted in document CCD/388, the existence of anomalous explosion-like earthquakes is very serious and the problem should be investigated carefully. Our examination will be described below.

Fifty-three Tibet-Assam shallow seismic events were investigated during 1963-1970, of which 50 are listed in table 4 of document CCD/388. Although we feel

21/ All seismographic stations have their own three-letter abbreviations, which are found in Seismograph Station Abbreviations and Co-ordinates, published in 1972 by the National Earthquake Information Center, United States Department of Commerce, or in the Regional Catalogue of Earthquakes, published semi-annually by the International Seismological Centre, Edinburgh.

-61-
uneasy about the accuracy of $Ms$ determination based on stations within narrow range of distance and azimuth from the foci, we did not examine $Ms$ and only re-examined the mb values from the published data source in order to check the anomalous events on the mb:M$s$ diagram in figure 5 of document CCD/388. The list is reproduced here partly with numbers in chronological order for each event in table 1. Table 1 shows where each event falls either in the earthquake-like (I), intermediate (II) or explosion-like (III) regions in the mb:M$s$ diagram adopted in document CCD/388. We also listed in table 1 the mean mb of the United States Coast and Geodetic Survey (USCGS) - the National Oceanic and Atmospheric Administration (NOAA) since July 1970 -- and the International Seismological Centre with the number of observations (or stations) used. The International Seismological Centre does not give mean mb when mb is reported by a very few stations and, for such events, the mb of individual station with station distance in degrees is given in table 1 in parentheses.

Figure 1A below is a reproduction of figure 5 in document CCD/388 giving the same order number to be referred to as that in table 1 for the convenience of identifying the events. Document CCD/388 pointed out two anomalous events above mb 5.0 which lie in the Basham-Marshall explosion region hatched in the mb:M$s$ diagram in this figure. They are No. 12 (8.1, 1965) and No. 46 (8.15, 1969). There are three other events in the explosion-like region (region III) with mb = 5.0, that is, No. 32 (7.13, 1968), No. 40 (8.25, 1968) and No. 41 (8.29, 1968). Document CCD/388 takes mb probably from PDE or EDR of NOAA. For several events mb adopted by document CCD/388 and mean mb of USCGS given in the Bulletin of the International Seismological Centre are slightly different as indicated by foot-note a/ in table 1 (Nos. 9, 10, 13, 16, 17, 18, 19, 20, 21, 24). Except Nos. 9 and 10, the mean mb's given in the Bulletin of the International Seismological Centre are 0.1-0.2 smaller than mb adopted by document CCD/388, which moves the points in mb:M$s$ diagram in the direction of the earthquake-like region.

The number of observations used to calculate the mean mb can be taken as a measure of the reliability of the mb value. mb of the anomalous event No. 12 seems to be based on mb at SHL (India, $\Delta = 7^\circ$) alone ($\Delta$ means epicentral distance). In the Bulletin of the International Seismological Centre, we also found mb 4.9 at EKA (Scotland, $\Delta = 67^\circ$), beside mb 5.5 at SHL of $\Delta$ of only 7$^\circ$. To adopt the mb value at near stations is generally questioned and ISC excludes as a rule mb at stations $\Delta < 21^\circ$ in the calculation of mean mb. Thus we have to consider that the mb 5.5 of event No. 12 is of poor reliability. The simple mean of two mb's at SHL and EKA is 5.2, but more weight should be given to EKA of a greater epicentral distance. Anyway the mb of this event must be much smaller than 5.5, shifting the position in the mb:M$s$ diagram certainly well outside the explosion-like region.

In figure 2 the number of reported P arrival times and mb values in the Bulletin of the International Seismological Centre are shown. In the figure, the number of P reports of event No. 12 of mb 5.2 seems too few compared with other events of the same magnitude. It suggests that even mb 5.2 for No. 12 is too large. Thus we cannot agree that this event should be accepted as an example of explosion-like anomalous events.

The mb 5.2 of another anomalous event No. 46 is the mean of four stations, as shown in table 2, namely, mb 5.0 at GIL (Alaska, $\Delta = 74^\circ$), mb 5.1 at PMR (Alaska, $\Delta = 75^\circ$) and mb 5.7 at BNG (Central African Republic, $\Delta = 76^\circ$) and mb 5.0 at BUL (Rhodesia, $\Delta = 81^\circ$). The mean seems strongly affected by the
value at BNG, and a recent investigation by Miyamura, 1972 (appendix), 22/ shows that the station correction to be added to the mb at BNG for Central Asian events is -0.13 ± 0.29. It is noticed that the standard deviation of mb variations at BNG is rather large at ± 0.29. As listed in table 1, the ISC mean mb for this event is mb 4.9 from nine observations and, according to the above consideration, mb 5.2 for this event seems to be somewhat large. Figure 2 indicates that the ISC mean mb 4.9 is reasonable in relation to the number of P reports. Thus we can move this event at least from the explosion-like region to the intermediate region in the mb:Ms diagram by changing mb from 5.2 to 4.9.

Three explosion-like events, Nos. 32, 40 and 41 with mb 5.0 or less are near the border of regions II and III on mb:Ms diagram in figure 1A and their mb's are based on four or five stations, as shown in table 2. The ISC mean values based on a larger number of observations for them are 0.1-0.2 smaller than USCGS (NOAA) mean values and these events will move from the explosion-like region into the intermediate region.

As table 1 shows, the mb values of USCGS (NOAA) which document CCD/388 adopted are generally based on fewer observations than the ISC mean. Furthermore ISC excludes near and regional stations to reject effects of regional inhomogeneity of the upper mantle structure on mb values and also the data are obtained in principle by re-examined interpretations. Accordingly, it is reasonable to think that ISC mb is a better estimate of mb than NOAA mb, which is rather preliminary. Adopting ISC mean mb's and Ms's of document CCD/388, we constructed mb:Ms diagram as shown in figure 1B below. This latter diagram shows no point in the explosion-like region (region III) for all magnitude ranges. There remain many events of mb less than 5.0 in the intermediate region (region II), but no event with mb ≤ 5.0 is even in the intermediate region. The Tibet-Assam shallow seismic events are thus considered to be all normal earthquake-like events at least for mb not less than 5.0 and they are clearly separated from explosion-like as well as from the intermediate region in the mb:Ms diagram, when we adopt ISC mean mb. We cannot deny that many events with mb less than 5 are in the intermediate region. However, it is still open for discussion whether we could extend the explosion-like region bounded by Ms = 0.5 mb - 1.5 to the unhatched region of mb less than 5.

Anyway, we have reached a somewhat different conclusion on the Tibet-Assam "anomalous" events and this new interpretation arises only from the mb values adopted. It indicates that the determination of mb on a more appropriate basis is necessary to apply mb:Ms method of discrimination for a comprehensive test ban. For the discussion of the threshold of verification, an agreement on mb value for each seismic event is also necessary.

Although it is very difficult to approach the true value of mb, the urgent need is to reach an agreement on the determination of mb, namely, by what method and on what data. We made some preparatory work to select reliable stations for the mb determination in the existing international seismological routine in order to provide a practical basis for this problem.

22/ The appendix is available for consultation at the secretariat of the Conference of the Committee on Disarmament.
4. Selection of reliable stations for the routine determination of body-wave magnitude for a comprehensive test ban

More than 500 seismological stations in different countries of the world are now co-operating in the routine rapid service of Preliminary Determination of Epicentres (PDE) of the National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce in sending their seismometric interpretations by telegram or by air mail every day or every week. The collected data are used to calculate the epicentre co-ordinates, focal depths and magnitudes by computer and the results are printed and distributed as PDE after a few months to the contributing stations, interested institutes and individual scientists of the world. All data used in PDE are also published subsequently as Earthquake Data Reports (EDR). The seismic events of the world are now routinely detected and located by this rapid service and, when we discuss the detection and identification of underground nuclear explosions, it is indispensable to be well acquainted with the present state of this service in order to investigate a practically feasible seismic verification system for a comprehensive test ban.

As reviewed in document CCD/363/Rev.1, short-period body-wave magnitudes have been systematically determined in PDE service for almost all seismic events located and have now become a useful measure of the size of event down to the smallest detectable earthquakes. However, as described in the previous sections with reference to the working papers presented by the United Kingdom and the United States, fluctuation of mb is very critical in relation to the seismological verification for explosions. It is necessary to avoid argument about the adopted magnitude values among the parties when the estimation of event size or discrimination needs the magnitude values. Especially, when the mb differs from station to station very much for a certain event and consequently different mean mb's are obtained for different combination of stations, we need to have a mutually agreed magnitude value.

For the routine monitoring of earthquakes, PDE service seems to be the only workable basis at present and we investigated the actual state of the mb determination of PDE. The details of the investigation can be found in the paper of Miyamura, 1972. Station biases of mb for different stations are obtained for the Nevada test site and Eastern Kazakh explosions separately.

As is shown in the appendix, reliable teleseismic stations for mb determination are as follows:

1. For NTS: CPO (United States of America); PMR, COL, GIL (Alaska); LPS (El Salvador); MBC, NP-, ALE (Canada); SJG (Puerto Rico); CAR (Venezuela); KTG (Greenland); LPS (Bolivia); KJN, NUR (Finland); TSK (Japan); BNS, GRF, FUR (Federal Republic of Germany); MOX, CLL (German Democratic Republic);

2. For Eastern Kazakh: NDI, SHL, POO, HYB (India); NUR, KJN, KEV (Finland); COP (Denmark); CLL, MOX (German Democratic Republic); GRF, FUR, STU, BNS (Federal Republic of Germany); NOR, KTG (Greenland); TSK, OIS (Japan); GIL, COL, PMR (Alaska); NP-, MBC, INK, CMC, PEC, GWC, FFS, EDM, PNT (Canada); BNG (Central African Republic); BUL (Rhodesia); PRE (South Africa); NEW, LON, LFL, LAO, BOZ, BMO, DUG, UBO, EUR, GOL, BKS, CPO, ALQ, WMO, TFO (United States of America); MUN, PMG (Australia).
Comparing the total number of stations reporting P arrival times to NOAA, the number of the above stations seems to be very small and, in reality, quite insufficient for reliable mb determination.

There are many other sensitive stations, such as UPP, KIR, UME, HFS (Sweden), SOD (Finland), KHC, PRU (Czechoslovakia), MAT, DDR (Japan), YKC (Canada), WRA, ASP (Australia), SPA (Antarctica etc., which have certainly a potentiality for reporting mb data, but have not been sending them to NOAA. For example, MAT has begun reporting mb recently with fair reliability. We can include some of them and invite many others to report regularly not only P arrival times, but also mb data to NOAA.

It is quite regrettable that some of the above-mentioned reliable stations, such as WMO and TFO, recently discontinued their reports to NOAA. Geographically uneven distribution of reliable stations for mb determination is clearly observed, as shown in figures 11 and 12 of the appendix, with respect to the epicentres and more reports from the vast blank areas of Asia, Africa and South America are especially needed.

In order to select key stations for the mb determination of seismic events in different parts of the world, the present investigation suggests that the urgent need is to increase the reporting stations. To begin with, we have to use the above selected stations plus several reliable sensitive stations, such as MAT, HFS and YKC.

A rapid seismological routine service based on many stations in many different parts of the world like FDE service is indispensable to the verification for a comprehensive test ban. Monitoring only by a small number of array stations may not be sufficient to secure unbiased mb values of seismic events in various parts of the world, though this problem has not yet been fully examined.
<table>
<thead>
<tr>
<th>No.</th>
<th>DATE</th>
<th>TIME</th>
<th>MAG. mb</th>
<th>Ms</th>
<th>REGION</th>
<th>USCGS mb/NUMBER OF OBSERVATIONS (STA. Δ)</th>
<th>ISC mb/NUMBER OF OBSERVATIONS (STA. Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 July 1963</td>
<td>0719</td>
<td>4.2</td>
<td>3.90</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8 Oct. 1963</td>
<td>0251</td>
<td>5.4</td>
<td>4.33</td>
<td>II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16 Nov. 1963</td>
<td>1139</td>
<td>4.7</td>
<td>3.93</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7 Jan. 1964</td>
<td>0450</td>
<td>5.0</td>
<td>4.38</td>
<td>I</td>
<td>5.0/COl</td>
<td>(5.0/COl,72°)</td>
</tr>
<tr>
<td>5</td>
<td>27 Jan. 1964</td>
<td>0529</td>
<td>4.9</td>
<td>3.87</td>
<td>II</td>
<td>4.9/COl</td>
<td>(5.4/COl,74°)</td>
</tr>
<tr>
<td>6</td>
<td>30 Apr. 1965</td>
<td>0713</td>
<td>4.4</td>
<td>3.96</td>
<td>I</td>
<td>4.4/COl</td>
<td>(4.5/COl,75°)</td>
</tr>
<tr>
<td>7</td>
<td>4 June 1965</td>
<td>1556</td>
<td>5.0</td>
<td>3.87</td>
<td>II</td>
<td>5.0/2</td>
<td>(5.3/SHL,7°)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>31 July 1965</td>
<td>1636</td>
<td>4.9</td>
<td>4.27</td>
<td>I</td>
<td>4.9/2</td>
<td>4.8/3</td>
</tr>
<tr>
<td>9</td>
<td>31 July 1965</td>
<td>1707</td>
<td>4.7a/4</td>
<td>4.81</td>
<td>I</td>
<td>4.8/4</td>
<td>5.0/7</td>
</tr>
<tr>
<td>10</td>
<td>31 July 1965</td>
<td>1901</td>
<td>4.4a/4</td>
<td>4.40</td>
<td>I</td>
<td>4.7/4</td>
<td>4.8/8</td>
</tr>
<tr>
<td>11</td>
<td>31 July 1965</td>
<td>2144</td>
<td>4.9</td>
<td>4.60</td>
<td>I</td>
<td>4.9/4</td>
<td>5.0/9</td>
</tr>
<tr>
<td>12</td>
<td>1 Aug. 1965</td>
<td>1414</td>
<td>5.5</td>
<td>3.94</td>
<td>III</td>
<td>5.5/SHL,7°</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1 Aug. 1965</td>
<td>2009</td>
<td>5.3a/4</td>
<td>4.78</td>
<td>I</td>
<td>5.2/8</td>
<td>63</td>
</tr>
<tr>
<td>14</td>
<td>2 Aug. 1965</td>
<td>1749</td>
<td>4.8</td>
<td>4.35</td>
<td>I</td>
<td>4.8/4</td>
<td>71</td>
</tr>
<tr>
<td>15</td>
<td>6 Oct. 1965</td>
<td>0803</td>
<td>5.4</td>
<td>4.10</td>
<td>II</td>
<td>5.4/3</td>
<td>79</td>
</tr>
<tr>
<td>16</td>
<td>9 Dec. 1965</td>
<td>2026</td>
<td>5.3a/4</td>
<td>4.47</td>
<td>I</td>
<td>5.1/3</td>
<td>44</td>
</tr>
<tr>
<td>17</td>
<td>31 Jan. 1966</td>
<td>0235</td>
<td>5.6a/4</td>
<td>4.87</td>
<td>I</td>
<td>5.4/12</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>14 Mar. 1966</td>
<td>0442</td>
<td>4.9a/4</td>
<td>4.46</td>
<td>I</td>
<td>4.8/7</td>
<td>17</td>
</tr>
<tr>
<td>19</td>
<td>27 May 1966</td>
<td>1435</td>
<td>4.8a/4</td>
<td>4.34</td>
<td>I</td>
<td>4.7/6</td>
<td>36</td>
</tr>
<tr>
<td>20</td>
<td>11 Sept. 1966</td>
<td>1555</td>
<td>5.0a/3</td>
<td>3.77</td>
<td>II</td>
<td>4.8/STU,BUL</td>
<td>67</td>
</tr>
<tr>
<td>21</td>
<td>26 Sept. 1966</td>
<td>0510</td>
<td>5.6a/4</td>
<td>5.26</td>
<td>I</td>
<td>5.5/14</td>
<td>67</td>
</tr>
<tr>
<td>22</td>
<td>26 Sept. 1966</td>
<td>0603</td>
<td>4.2</td>
<td>3.59</td>
<td>I</td>
<td>4.2/PO0,20</td>
<td>74</td>
</tr>
<tr>
<td>23</td>
<td>11 Mar. 1967</td>
<td>1656</td>
<td>5.3</td>
<td>4.69</td>
<td>I</td>
<td>5.3/12</td>
<td>19</td>
</tr>
<tr>
<td>24</td>
<td>14 Mar. 1967</td>
<td>0658</td>
<td>5.9a/5</td>
<td>5.54</td>
<td>I</td>
<td>5.8/16</td>
<td>16</td>
</tr>
<tr>
<td>25</td>
<td>7 July 1967</td>
<td>2256</td>
<td>4.9</td>
<td>3.71</td>
<td>II</td>
<td>4.9/STU,COl</td>
<td>47</td>
</tr>
<tr>
<td>26</td>
<td>15 Aug. 1967</td>
<td>0921</td>
<td>5.7</td>
<td>5.07</td>
<td>I</td>
<td>5.7/15</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 1: Tibet-Assam shallow earthquakes, investigated in document CCD/388 as including explosion-like seismic events.
Table 1 (continued)

<table>
<thead>
<tr>
<th>NO.</th>
<th>DATE</th>
<th>TIME</th>
<th>mb</th>
<th>Ms</th>
<th>REGION</th>
<th>USCGS mb/NUMBER OF OBSERVATIONS (STA. Δ)</th>
<th>ISC mb/NUMBER OF OBSERVATIONS (STA. Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>16 Feb. 1968</td>
<td>0537</td>
<td>4.8</td>
<td>4.51</td>
<td>I</td>
<td>4.8/6</td>
<td>11</td>
</tr>
<tr>
<td>28</td>
<td>28 June 1968</td>
<td>2034</td>
<td>4.8</td>
<td>3.58</td>
<td>II</td>
<td>4.8/3</td>
<td>48</td>
</tr>
<tr>
<td>29</td>
<td>30 June 1968</td>
<td>0504</td>
<td>4.8</td>
<td>3.40</td>
<td>II</td>
<td>4.8/3</td>
<td>54</td>
</tr>
<tr>
<td>30</td>
<td>1 July 1968</td>
<td>0311</td>
<td>4.3</td>
<td>3.00</td>
<td>II</td>
<td>4.3/BUL,81°</td>
<td>53</td>
</tr>
<tr>
<td>31</td>
<td>4 July 1968</td>
<td>0645</td>
<td>4.7</td>
<td>3.46</td>
<td>II</td>
<td>4.7/3</td>
<td>48</td>
</tr>
<tr>
<td>32</td>
<td>13 July 1968</td>
<td>0605</td>
<td>5.0</td>
<td>3.46</td>
<td>III</td>
<td>5.0/5</td>
<td>56</td>
</tr>
<tr>
<td>33</td>
<td>14 July 1968</td>
<td>1812</td>
<td>4.9</td>
<td>3.54</td>
<td>II</td>
<td>4.9/6</td>
<td>54</td>
</tr>
<tr>
<td>34</td>
<td>15 July 1968</td>
<td>0509</td>
<td>4.8</td>
<td>3.39</td>
<td>II</td>
<td>4.8/COL,73°</td>
<td>60</td>
</tr>
<tr>
<td>35</td>
<td>16 July 1968</td>
<td>2223</td>
<td>4.8</td>
<td>3.45</td>
<td>II</td>
<td>4.8/4</td>
<td>54</td>
</tr>
<tr>
<td>36</td>
<td>23 July 1968</td>
<td>2051</td>
<td>4.9</td>
<td>3.43</td>
<td>II</td>
<td>4.9/4</td>
<td>59</td>
</tr>
<tr>
<td>37</td>
<td>26 July 1968</td>
<td>1244</td>
<td>4.9</td>
<td>3.45</td>
<td>II</td>
<td>4.9/5</td>
<td>61</td>
</tr>
<tr>
<td>38</td>
<td>23 Aug. 1968</td>
<td>1201</td>
<td>4.8</td>
<td>3.46</td>
<td>II</td>
<td>4.8/4</td>
<td>64</td>
</tr>
<tr>
<td>39</td>
<td>24 Aug. 1968</td>
<td>1426</td>
<td>4.6</td>
<td>3.35</td>
<td>II</td>
<td>4.6/SHL,COL</td>
<td>68</td>
</tr>
<tr>
<td>40</td>
<td>25 Aug. 1968</td>
<td>1755</td>
<td>4.8</td>
<td>3.28</td>
<td>III</td>
<td>4.8/4</td>
<td>64</td>
</tr>
<tr>
<td>41</td>
<td>29 Aug. 1968</td>
<td>1951</td>
<td>5.0</td>
<td>3.48</td>
<td>III</td>
<td>5.0/4</td>
<td>67</td>
</tr>
<tr>
<td>42</td>
<td>1 Sept. 1968</td>
<td>0559</td>
<td>5.0</td>
<td>3.59</td>
<td>II</td>
<td>5.0/5</td>
<td>72</td>
</tr>
<tr>
<td>43</td>
<td>3 Sept. 1968</td>
<td>1745</td>
<td>4.9</td>
<td>3.43</td>
<td>II</td>
<td>4.9/3</td>
<td>68</td>
</tr>
<tr>
<td>44</td>
<td>4 Sept. 1968</td>
<td>0140</td>
<td>4.8</td>
<td>4.05</td>
<td>I</td>
<td>4.8/COL,70°</td>
<td>70</td>
</tr>
<tr>
<td>45</td>
<td>11 Sept. 1968</td>
<td>0307</td>
<td>4.3</td>
<td>3.52</td>
<td>I</td>
<td>4.3/BNG,76°</td>
<td>72</td>
</tr>
<tr>
<td>46</td>
<td>15 Aug. 1969</td>
<td>0715</td>
<td>5.2</td>
<td>3.57</td>
<td>III</td>
<td>5.2/4</td>
<td>55</td>
</tr>
<tr>
<td>47</td>
<td>24 Nov. 1969</td>
<td>0201</td>
<td>4.6</td>
<td>4.00</td>
<td>I</td>
<td>4.6/5</td>
<td>77</td>
</tr>
<tr>
<td>48</td>
<td>8 Feb. 1970</td>
<td>1907</td>
<td>4.5</td>
<td>4.05</td>
<td>I</td>
<td>4.5/4</td>
<td>15</td>
</tr>
<tr>
<td>49</td>
<td>8 May 1970</td>
<td>1108</td>
<td>4.5</td>
<td>3.55</td>
<td>I</td>
<td>4.5/KJN,NP-</td>
<td>33</td>
</tr>
<tr>
<td>50</td>
<td>24 June 1970</td>
<td>0034</td>
<td>4.8</td>
<td>4.53</td>
<td>I</td>
<td>4.8/8</td>
<td>45</td>
</tr>
</tbody>
</table>

a/ mb adopted in document CCD/388 is slightly different from mb given in the Bulletin of the International Seismological Centre.
### Table 2

Station mb in EDR for Tibet-Assam events suspected as explosion-like in document CCD/388

<table>
<thead>
<tr>
<th>EVENT</th>
<th>EDR 56-68</th>
<th>BULL</th>
<th>ISC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STA.</td>
<td>DIST.</td>
<td>mb</td>
</tr>
<tr>
<td>No. 12</td>
<td>SHL</td>
<td>7.2</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>mb on 1 obs.</td>
<td>5.5</td>
<td>no ISC mean is given</td>
</tr>
<tr>
<td>No. 32</td>
<td>NP-</td>
<td>71.6</td>
<td>4.9%</td>
</tr>
<tr>
<td></td>
<td>COL</td>
<td>73.5</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>BNG</td>
<td>75.8</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>BUL</td>
<td>80.9</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>mb on 4 obs.</td>
<td>5.0</td>
<td>no ISC mean is given</td>
</tr>
<tr>
<td>No. 40</td>
<td>SHL</td>
<td>5.4</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>GIL</td>
<td>73.5</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>PMR</td>
<td>74.9</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>BUL</td>
<td>81.1</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>mb on 4 obs.</td>
<td>4.8</td>
<td>no ISC mean is given</td>
</tr>
<tr>
<td>No. 41</td>
<td>NUR</td>
<td>54.6</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>COL</td>
<td>73.4</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>PMR</td>
<td>74.9</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>BUL</td>
<td>81.2</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>mb on 4 obs.</td>
<td>5.0</td>
<td>no ISC mean is given</td>
</tr>
<tr>
<td>No. 46</td>
<td>GIL</td>
<td>73.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>PMR</td>
<td>75.0</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>BNG</td>
<td>76.1</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>BUL</td>
<td>81.1</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>mb on 4 obs.</td>
<td>5.2</td>
<td>no ISC mean is given</td>
</tr>
</tbody>
</table>

\[a/\] Arithmetic mean is 4.94.
Figure 1

mb : MS Diagram for Tibet-Assam shallow seismic events

1A : mb (CCD/388) versus MS (CCD/388)

1B : mb (ISC) versus MS (CCD/388)

mb: Ms diagrams of Tibet-Assam shallow earthquakes investigated in document CCD/388 as an example of population including explosion-like seismic events. 1A is mb: Ms diagram same as in figure 5 of document CCD/388. Numbers attached to the points are the chronological order of numbers given in table 1. 1B is mb: Ms diagram, taking the International Seismological Centre mean mb instead of mb adopted by document CCD/388 from USGS (NOAA).

I, II and III are earthquake-like, intermediate and explosion-like regions in the mb: Ms diagram adopted by document CCD/388 and the hatched part is explosion domain by Basham-Marshall, 1972.
Number of P reports and mb of Tibet-Assam shallow seismic events a/

The relation of the number of P arrival time reports N and mean mb by the International Seismological Centre.
I. General provisions

Any agreement banning chemical weapons should include:

1. A clear understanding whereby future agreed provisions for the prohibition of the development, production and stockpiling of chemical weapons are not to be interpreted as in any way limiting or detracting from the obligations assumed by the parties under the Geneva Protocol of 1925.

2. Provisions to ensure that the agreement should be implemented in a manner designed to avoid hampering the research, development, production, possession, transfer and application of chemical agents for peaceful purposes or hindering the economic or technological development of States parties.

3. An undertaking not to assist, encourage or induce any State, group of States or international organizations in prohibited activities.

4. Undertakings to facilitate, and a right to participate in, the fullest possible exchange of chemical agents, equipment material and scientific and technological information for the use of such chemical agents for peaceful purposes.

5. A recognition of the principle that a substantial portion of the savings derived from measures in the field of disarmament should be devoted to promoting economic and social development, particularly in the developing countries.


24/ Ibid., Supplement for 1971, document DC/234, annex C.
6. Security guarantees which in the interest of many countries should go beyond those envisaged in already existing disarmament and non-armament agreements.

II. Scope of the prohibition

7. Discussions in the Committee show a basic agreement on the objective of the negotiations relating to chemical weapons, namely, that they should aim, in accordance with relevant United Nations resolutions, at reaching a comprehensive ban, covering the development, production and stockpiling of all chemical weapons, their equipment and means of delivery, as well as the destruction of existing stocks.

8. The degree of danger represented by the use of chemical agents for purposes of war depends, besides their toxicity, to a high degree on the protection available, as well as on the means of delivery. Since adequate protection against any kind of chemical weapons is not available to the greater part of the world population, even less-toxic agents can create as great a danger as highly toxic ones and therefore should be prohibited.

9. It is essential that the prohibition of chemical weapons should be coupled with adequate verification. The question of verification has both technical and political aspects which should be reconciled and therefore it is connected with the scope of the prohibition. Solutions to the problems of scope and verification should not be discriminatory and should maintain an acceptable balance of obligations and responsibilities for all States. A partial solution with respect to the scope of the activities to be prohibited, which would only ban the development and production of chemical weapons, will be particularly discriminatory and will not be acceptable to many countries, specially to those which have abstained from procuring such weapons.

10. In the text of the Treaty, a comprehensive ban could deal with the problem of scope by a general purpose criterion, while more detailed provisions could be elaborated in the annexes to the Treaty. These agreed provisions may be revised and updated by the international control organ referred to in paragraph 14 below.

III. Verification and system of control

11. The purpose of the verification system in a treaty prohibiting chemical weapons should be to give every party a reasonable assurance of compliance of the prohibition. Such assurance could be provided through a combination of national and international measures, which would complement and supplement each other, thereby providing an acceptable system which would ensure effective implementation of the prohibition. At least the following basic elements should be included: (a) the self-control of States, (b) national means of verification and (c) international measures of verification.

A. The self-control of States

12. The self-control of States parties to the Treaty might encompass:
(a) declarations, at the time of entering into force of the prohibition, as regards national activities related to production and development of chemical weapons and agents, particularly concerning the destruction of existing stockpiles;

(b) measures aimed at implementing the prohibition, including the enactment of laws and regulations;

(c) the organization of a national system of control and control body with authorization to co-operate with the international control organ and

(d) informing the international control organ of these measures of self-control.

B. National means of verification

13. Every State could use its own means to verify the observance of the prohibition, in accordance with international law and the United Nations Charter. The States parties might undertake to consult one another and to co-operate in solving any problems which might arise in relation to the objective of, or in application of, provisions of the Treaty. Consultation and co-operation might also be undertaken through appropriate international procedures within the framework of the United Nations and in accordance with its Charter.

C. International measures of verification

14. International measures of verification should be performed by a qualified and independent international control organ to be designated by the States parties, and the results should be made available to all parties on an automatic and fact-finding basis. They might comprise collection, analysis and circulation of relevant data and assistance to States parties in the development of self-control as well as national means of verification. On the other hand, the international control organ should receive full assistance of States parties in the development of international verification measures, including relevant technology at the disposal of States parties. The verification system should encompass all activities related to development, production and stockpiling of chemical warfare agents. As a non-recurrent measure, international inspection could also be specially provided for in order to verify destruction of stocks, in a manner to be agreed upon between the international control organ and the State party concerned.

15. The international verification system should, within the provisions of the Treaty, be reviewed and as appropriate improved, taking into account new scientific and technological achievements. The verification system should be conceived and implemented in such a way as to avoid the disclosure of scientific, industrial and commercial secrets.
IV. Complaints procedure

16. Any State party might, as a last resort, lodge a complaint with the Security Council concerning an alleged breach of the provisions of the Treaty by another State party.

17. The complaining State party should submit all possible evidence, including a report or reports, which might be prepared by the international control organ mentioned in paragraph 14 above, to the Security Council.
9. UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Working paper on a review of the United Kingdom seismological research and development programme (CCD/401)

[Original: English] [28 June 1973]

Introduction

It is some eight years since a general review of the research and development programme in the United Kingdom on the seismological problems of a comprehensive test ban was presented to the Conference of the Committee on Disarmament (ENDC/155) 25/ and a detailed account was published later in 1965 by the United Kingdom Atomic Energy Authority under the title The Detection and Recognition of Underground Explosions.

Beginning in 1969, a series of more specialized working papers described the development of research in the United Kingdom on the effectiveness of various discrimination criteria (ENDC/258), 26/ the capacity of a network of arrays deployed especially for comprehensive test ban control (CCD/296 27/ and CCD/366 28/), and the precision with which seismic yields could be estimated (CCD/363/Rev.1). 28/ A companion, more specialized, working paper tabled simultaneously (CCD/402) describes attempts to improve the estimates of the depth at which a given seismic event occurred. Copies of seismological studies made by the United Kingdom of the Rulison, Gasbuggy and Medeo explosions (AWRE Reports Nos. 033/70 and 046/70) and of a detailed analysis of explosions and earthquakes recorded in 1966 from the Sino-Soviet areas (AWRE Report No. 05/73) have also been distributed to delegations. This paper is a review of the whole United Kingdom programme, and an explanation of the underlying themes which determine the emphasis of that programme. The paper starts with the present status of the four recording stations, which, it will be recalled, were first deployed on a research and development basis in 1962.

The four array stations

The array at Yellowknife in the Northwest Territory of Canada is the most advanced of all, and this is due to the independent efforts of Canada. These include massive technical improvements to the short-period array since it was first deployed in 1963, and the establishment of a long-period array and a standard station compatible with the World-Wide Standard Seismograph Network. The

25/ Ibid., Supplement for January to December 1965, document DC/227, annex I, sect. C.
28/ Ibid., Supplement for 1972, document DC/235, annex B.

-75-
Seismology Division of the Canadian Department of Energy, Mines and Resources has demonstrated that the operation and development of monitoring stations in extreme climatic environments is perfectly viable.

Another example of a difficult environment is the Northern Territory of Australia where the Warramunga array is operated by the Seismology Department of the Australian National University. Since 1965, when it was installed, it has provided excellent research material for both the United Kingdom programme and the University seismologists. A single long-period station has been established at the array, and sites for two others have been prepared by the University department should a long-period array be considered desirable. Subject to agreement with the University, funds allocated this year will be used to put into effect the technical improvements developed in Australia as a result of operational experience.

The array at Gauribidanur in southern India also has a record of excellence since it was installed in 1965. The efforts of the Bhabha Atomic Research Centre (BARC) of India have made it the best housed and best manned station of the four. To the original short-period array, a long-period and microbarograph array has been added, and the Seismology Division of the Centre have recently designed and installed a special-purpose computer for processing the array data. A programme of technical improvements is planned for this year.

The array at Eskdalemuir in Scotland is the oldest of the four, having been in continuous service since 1922. It is at this station that technical developments are proved before being accepted for general use. There are no plans for an array of long-period seismometers at Eskdalemuir. This is partly because the Swedish Research Institute for National Defence service the magnetic tape recorder which they invited the United Kingdom to install at the long-period array at Hagfors, and partly because the nearby station of NORSAR in Norway includes a large long-period array from which recordings are also available on request.

Much of the material for the United Kingdom working papers owes its source to the arrays, and this is an appropriate forum in which to acknowledge, once more, the United Kingdom debt to Australia, Canada, India and Sweden for the regular supply and quality of this material. The accumulated experience in this field of those countries is of major value.

It should also be mentioned that the United Kingdom Institute of Geological Science has recently installed its own magnetic tape recorder at the short-period array at Brasilia and these recordings are also available, on request, in support of the United Kingdom programme.

The recordings from these stations are collected in a data laboratory at the Blacknest laboratories, where the research team responsible for implementing the United Kingdom seismological programme in support of the comprehensive test ban problems is located. Original array data covering a period of two and a half years is continuously maintained there, as well as a much longer sequence of explosion data. The material and the processing facilities are utilized from time to time by other establishments in the United Kingdom and overseas. A small seismological recording station is maintained near the laboratory and much of the experimental work is tested at this station. It is here, for example, that an instrument having the Kirnos-type response, which is often used by Soviet seismologists for recording the whole of the P-wave spectrum (wide band, for P), has been installed.
to study the problems of using P-wave magnitudes ($m_b$) to estimate yields (CCD/363/Rev.1). 29/ P-waves of explosions which were recorded during this period were so obviously different in frequency content from earthquakes of equivalent size that an example was published in the United Kingdom journal Nature 30/ and the records are reproduced here (see figure 1 below) together with a sketch of the amplitude response of the three recording systems concerned and the characteristic amplitude spectrum of the microseismic noise band which presently inhibits the value of the system for comprehensive test ban purposes.

**Broad-band recording**

The only scientifically valid way of tackling the discrimination problem is of course to record the complete spectrum of the radiated signal. With filtering, either during processing or by limiting the response of the recording instrument, the signal-to-noise ratio improves, but at the same time information which may be characteristic of the source is lost. Conversely, as the recording band is broadened, the signal-to-noise ratio decreases. The accompanying records in figure 1 illustrate the dilemma very clearly.

The striking records seen through the wide-band system did, however, pose the question: can the amplitude of the microseismic noise, relative to the signal, be reduced without filtering away source information in the signal? After another look at earlier work on the problem, it was decided to have another try. The observation on which a successful outcome would depend is that the microseismic noise propagates at much lower velocity than the signal, and is highly directional in the United Kingdom. In principle, therefore, a properly designed array of suitably tuned seismographs should allow signals to be separated from coherent microseisms by standard processes of beam forming, in a way similar to that illustrated for two signals in document CCD/386, 31/ which does not destroy information carried by the signals. It would also be possible to attempt a well known but more complex technique of predicting the character of coherent microseisms after the onset of the signal from an analysis of their character for a period preceding the signal onset. If the noise characteristics are known, they can be removed from the recording of mixed noise and signal to leave an enhanced and undistorted signal.

To collect data for testing these ideas, an array of four such instruments has recently been deployed near the Blacknest laboratory, and data is now being accumulated. The spacing of the instruments will be critical, but fortunately there is a large number of suitable sites, already equipped with telemetry, on which modifications can be made. The improvement in the signal-to-noise ratio of 100, which might dramatically reduce the present reliance on the $m_b$:$M_s$ discriminant, cannot be hoped for. But, even if a factor of 10 were to be achieved, it would be

29/ Ibid.
30/ Vol. 239, No. 92, 1972, pp. 154-155.
a powerful answer to the question how to discriminate between multiple shots and earthquakes, if it could be affirmed with certainty that the larger explosions in the series would be detected by a wide-band system.

The concept of this new United Kingdom array highlights the theme underlying much of the thinking which now focuses the United Kingdom's programme. This is to try every possible way of broadening the spectral window through which seismic signals are observed. Broad-band recording is the direct way, and the data recording systems must be designed together with the noise reducing processing system as a single operation. There is, however, another possibility. As more is learnt about the properties of the earth's transmission paths, it becomes feasible to eliminate some effects by applying well-known techniques to the original narrow-band recordings. The upshot is in some degree to broaden the band. Such techniques have been applied to improve the chances of identifying the echo (pP) of a seismic event from the earth's surface and thereby increase the certainty with which the depth discriminant can be applied. This topic is the subject of the companion working paper (CCD/402).

**Computing seismograms**

Another study having a similar underlying principle has begun to produce results. The seismic events which give most cause for concern today are earthquakes, which are recorded with very simple P-wave trains and which lie in a "grey" area between explosions and earthquakes on the $m_M$ criterion; indeed a few do lie adjacent to the explosion population. The fact that the seismograms are simple, however, does lend itself to the technique of computing seismograms, which has been systematically developed in recent years by the combined efforts of teams at Blacknest and the University of Cambridge. Details of the work have been published in the scientific press, but this is perhaps the first occasion on which the attention of delegations of the Conference of the Committee on Disarmament has been especially drawn to the work in the context of a comprehensive test ban. In summary, when a source mechanism (and orientation of the fault in the case of earthquakes) and propagation path is assumed, and the characteristic filtering (response) of the seismographs is known, it is possible to compute the seismogram. If the source, its orientation, and the elastic properties of the transmission path have been correctly estimated, the computed seismogram would be identical with an observed seismogram, which is the subject of study. Though a great deal of trial and error is still necessary, none the less satisfying results on simple earthquakes have been achieved, and one such example is illustrated below (figure 2). Since there are not too many of this class of earthquake in the course of a year, the labour involved might be profitable. The great value of the technique, should it be proved, is the underlying certainty about decisions as to the nature of the source when the observed seismogram is copied rather precisely by selecting the right model for the source. Though many earlier attempts have been made to compute realistic seismograms, it is only now, with a sufficiently precise knowledge of the earth's interior and with access to large and fast digital computers, that the computation of simple seismograms may have practical merit.

A supplement to the modelling work is the compilation of a seismogram album or atlas. When complete, it will contain a wide variety of normal as well as unusual seismograms, which could well lead to the development of a crude pattern recognition system. In any case, its publication should be of considerable interest.
The mb problem

The mb:Ms and yield problems, which are caused by the variability of mb, have not been forgotten while these new developments have matured. It was suggested in the United Kingdom working paper CCD/363/Rev.1 that an important cause of the variability in the quantity mb was the absorption of the high frequency content of the P-wave with a consequent diminution of amplitude. The opportunity for the radiated P-energy to take a number of different paths, particularly within the top 500 kilometres or so, was also explained. A paper which provides the detailed evidence, entitled "P-wave complexity re-examined", is under publication in a scientific journal and it does much to explain the anomalies commonly observed in the first half minute of the short-period P-wave train. University interest has been stimulated by the possibilities of mapping these areas of high absorption and, once they are known or can be predicted, the necessary corrections to mb can be applied.

Data processing

Finally, since the ideas behind the United Kingdom concept of a seismic array station processor (SASP) were presented in document CCD/386, the bulk of the equipment has been delivered at the Blacknest laboratories and the work on developing the system to its full potential has begun.
Figure 1

Shallow earthquake in E Siberia 18 May 1971 m<sub>s</sub> 5.8

Long-Period Band

Short-Period Band

Wide Band

Explosion in Novaya Zemlya 14 October 1970 m<sub>s</sub> 6.7

Long-Period Band

Short-Period Band

Wide Band

The band and amplitude of the noise spectrum varies with location. The expected maximum amplitude is shown.
Figure 1. The two sets of seismograms of the P-wave trains of an earthquake and an explosion illustrate two points made in the text: (a) the character of a recording is strongly dependent on the recording band or response of the seismograph system; (b) a wide-band seismograph retains the character of the source signature more faithfully than narrow-band systems. Note that that wide-band seismograph illustrates the difference between explosion and earthquake most clearly.

However, the large amplitude of microseismic noise within this band seriously limits the detection threshold of the wide-band seismograph. This noise is particularly noticeable as a sinusoidal motion preceding the P-signal onset on the lowermost record. If this noise were to be removed by frequency filtering, both wide-band records would look like the short-period band record, and the differences in the signatures lost. If the signatures of smaller events are to be preserved, the noise must be reduced by methods outlined in the text.
The lower seismogram is of an earthquake which occurred in S Kazakhstan USSR, and which was recorded at Yellowknife, Canada. The upper seismogram is an attempt to model this observation. In the model, the second large pulse is the surface reflection or echo (pP), which indicates shallow depth. Because the model and the observed seismograms are very similar, it is assumed that the second arrival on the observed seismogram is also pP.

On the $m_b$,$m_s$ criterion, this earthquake lies close to the explosion population. At first sight the record might appear to indicate two explosions fired 6 seconds apart, or perhaps a deeply buried explosion. It proved, however, impossible to model the record as closely using an explosion as the source; the earthquake source model gave a much closer resemblance in the details of the pulse shapes. It is suggested that the observed seismogram must, therefore, have been generated by an earthquake.
Introduction

One of the better methods of establishing that a distant seismic event is an earthquake is by demonstrating that it took place at a depth beyond reach of modern drilling techniques. The method is attractive because it has a well understood physical basis and is easy to apply and because, in monitoring a comprehensive test ban, it could eliminate a large number of earthquakes to leave a shorter list of unidentified events on which to apply other criteria. The use of depth criteria in conjunction with other criteria for identifying earthquakes is illustrated in ENDC/155 32/ and in the United Kingdom's AWRE Report 0-5/73, which was circulated informally to delegations of the Conference of the Committee on Disarmament earlier this year.

Identification of events using the depth criterion - P and pP waves

The identification of earthquakes using the depth criterion takes place in two stages. First, when computing the origin time and location (epicentre) of a seismic event from the arrival times of the P waves (elastic body waves in which particle motion is in the direction of propagation), it is also possible to obtain an estimate of the depth at which the event occurred. However, when recording stations are at distances of a few thousand kilometres from the epicentre, as they might be in a control network, the depth of seismic events is poorly controlled by the travel times of the P-waves. Indeed uncertainties in these depth estimates are such that one cannot be sure that an event is too deep to be an explosion until its depth estimated from the origin time-epicentre computations is greater than about 50 kilometres and, accordingly, only a small proportion of the total number of earthquakes is identified by this process. In the context of the comprehensive test ban, these events are usually described as "deep" earthquakes.

In all such studies of a set of seismic events, the deep earthquakes are eliminated in this way to leave a group of unidentified "shallow" events. Thereafter a more sensitive indicator of depth is used; this is the time interval between the wave which arrives at the station by the direct path (P) and the echo from the earth's surface, which seismologists call pP. This time interval is the time for the echo to travel to the surface above the source and back again to the depth of the source before following direct P to the receiver (see figure 1 below). If the velocity in the rocks above the source is known (or can be estimated from geological information), then multiplying this time interval by the velocity gives the extra distance pP has to travel compared to P. The depth of the

32/ Ibid., Supplement for January to December 1965, document DC/227, annex I, sect. C.
source is then roughly half this distance. The time of the first arrival P is normally easy to measure with sufficient precision. Ideally pP would be recorded as a clearly defined second arrival at distant stations. This second arrival would be identified as pP by its time separation from P which would be smaller at distant stations than at near stations. This is because pP follows a near vertical path from source to surface for signals that travel to distant stations, whereas the path for pP for signals recorded at near stations departs markedly from the vertical and so is longer. Another property of pP is that it is often of similar shape to P, but upside down, so a second arrival that can be shown to be inverted relative to P is very probably pP. In practice, pP is commonly difficult to identify on seismograms because other arrivals contribute to the complexity of the total P-wave train. For an earthquake, some of the stations in a network may not record pP at all, because energy is not radiated symmetrically about the source. Another difficulty is that, when shallow events occur in rocks having a high P-wave velocity, the time interval pP-P is so small that the first arriving P-wave obscures the arrival of pP.

Estimation of depths

The usefulness of pP-P observations on seismograms can, however, be extended by using those earthquakes for which the depth can be estimated from pP identified in a group of seismograms as a "master" set of events against which the total travel times may be calibrated. With these calibrated travel times, depths can be estimated of nearby earthquakes with no records of pP.

A proportion of earthquakes which occur below depths of about 15 kilometres can be so identified by the use of the echo, pP. It is so satisfactory a method of identifying earthquakes that, during recent years, a considerable effort has been made in the United Kingdom to find ways of aiding the identification of pP.

One reason why pP is difficult to identify for very shallow events is because a pulse passing through the earth tends to be smeared out. A seismograph sharply tuned for optimum detection of the P-wave, as it must be for monitoring a comprehensive test ban, also has the effect of smearing out a pulse. An impulse is converted by the seismograph into an oscillating wave train of two or three seconds' duration. The combined effect of earth and seismograph is to smear out P so much that, for very shallow events, P and pP overlap. More serious, however, is the smearing of the direction of first motion in both arrivals, which makes it difficult to decide if the second arrival is upside down relative to P, which would indicate that it is probably pP.

Spiking filter techniques

In principle, the effect of both the earth and seismograph can be removed from seismograms and several techniques to do this have been attempted in recent years. One which has attracted special attention in the United Kingdom requires four conditions to be satisfied. The first is that the seismogram must be fairly simple in character; this applies to those of explosions and of earthquakes that look like explosions. The second is a corollary of the first - the source must radiate a sharp impulse, often called a "spike" because of its shape. This is the P-wave before the transmission path exerts its smearing effect. Thirdly, the smearing or
absorption of the transmission path must be translated into quantitative terms. Finally, the "ringing" effect of the sharply tuned seismograph must be known.

The difficult part is to estimate the transmission path, but by limiting the experiment to relatively simple records, which would be the principal interest for a comprehensive test ban monitoring network, some useful results are possible. A filter, technically called a spiking filter, can be constructed by trial and error to remove the effects of the transmission path and seismograph and give the best approximation to the source impulse or spike.

Examples

Two examples of the use of a spiking filter are illustrated in figure 2 below. The uppermost record is the original Yellowknife seismogram of a nuclear explosion fired near the city of Bukhara to seal off a fire in an oil well. Though an experienced observer would be fairly confident of identifying pP in this particular case, the way in which the spreading of the impulses, and the ringing of the tuned seismograph smears together P and pP is well illustrated. Immediately below this seismogram is the record derived by applying a spiking filter. The spiked record displays P and the inverted echo pP much more clearly, and the time interval pP-P of 1.7 seconds can be measured much more precisely. Using a round figure of 3 km per second for the velocity of P waves in the sedimentary material, known from geological maps to be present at the site of the explosion, a depth of nearly 2.6 km is derived. The depth was actually 2.45 km.

The second example is taken from a seismogram recorded at Gauribidanur of an explosion (identified from the $m_D$ criterion) which occurred in Eastern Kazakhstan. pP cannot be verified from the seismogram. Either it is not present at all, or it overlaps almost completely with P. After spiking P and pP can be identified, the pP-P interval being 0.3 seconds. The map of the firing site reveals a "hard rock" type of geology in which the average P-wave velocity is probably about 5 kilometres per second. The depth of the event is therefore about 0.75 kilometres. The actual depth of this explosion is not known.

Value of the techniques

Though these are rather good examples of the use of the spiking technique to aid the identification of pP in relatively simple seismograms, it should be emphasized that often spiking simply verifies the interpretation of an experienced reader of seismograms and that there may be insurmountable difficulties in applying it reliably to seismograms with several arrivals. It does have the edge on the unaided eye in separating P overlapped by pP and in clearly demonstrating the characteristic inversion of pP compared to P. The technique itself has the advantage over others tried for this purpose in presenting a record which is essentially just another type of seismogram and which is therefore more confidently interpreted by a seismologist. Its principal contribution to the seismological problems of a comprehensive test ban is to increase the confidence with which doubtful events are categorized. The way in which the technique fits into the pattern of the United Kingdom research and development programme on the seismological problems of a comprehensive test ban, are described in document CCD/401.
Figure 1

FREE SURFACE

TO RECEIVER

SURFACE REFLECTED P (PP)

DIRECT P

d

EXPLOSION
Near Bukhara
21 May 1968

Spiked

Eastern Kazakhstan
22 September 1967
Introduction

A system of guarantees to ensure that all parties to the agreement are complying with the obligations they have assumed should be based on national forms of control combined with certain international procedures. This is the basis from which the present working paper proceeds. Of course, it is for each State party to the convention to determine the form and methods of implementing national control. The following considerations may be regarded as outlining possible ways of fulfilling the obligations of States parties, as provided for in article IV of the draft convention submitted by the socialist States on 28 March 1972 (CCD/361). 33/

National control committees

A State party to the convention establishes a national control committee as an element in the national system of control over the prohibition of the development, production and stockpiling of chemical weapons within the territory of the State concerned, under its jurisdiction or control. The national control committee should, by way of random verifications, supervise the destruction of stockpiles of chemical weapons and the closure of conversion to peaceful production of the chemical enterprises which had, before the conclusion of the convention, been engaged in production of means of warfare. It would also supervise compliance with the prohibition of the production of the means of delivery of chemical weapons. The composition of the national control committee could be determined by the State party to the convention. The committee could consist of representatives of governmental and public organizations, depending on the specific conditions existing in the country concerned. The committee staff could include specialists in chemistry and economics. Effectiveness of control is ensured by the modern methods available to specialists in chemistry. These include the use of detection apparatus, analysis of waste gases, analysis of waste water and soil at enterprises, the installation of sealed sensing devices, and visits to enterprises by the appropriate specialists representing the national committee. It is also desirable that the national control committees should, as necessary, be able to examine reports on research work carried out by various research institutions in the chemical industry and related fields. Internal

33/ Ibid., Supplement for 1972, document DC/235, annex B.
legislation should provide for the national control committees to submit reports to national Governments on their activities, and should also allow for the possibility of publishing such reports for general information.

Exchanges of information

The national system of control could also be accompanied by exchanges of information among States, on a voluntary basis, in the form of discussions on new data obtained as a result of scientific research on the development of new products for peaceful purposes.

Statistical analysis

Analysis of statistical data, contained in open publications, on the production and consumption of raw materials and semi-finished products could form one of the elements of control over the prohibition of chemical weapons. A comparison of the amount of chemicals (raw materials and semi-finished products) manufactured over a year or some other long enough period, with the volume of the consumption of chemicals for peaceful purposes, might to a certain degree provide evidence of the way in which a State is complying with the obligations it has assumed under the agreement. A sizable excess of production over consumption would give grounds for assuming that the surplus was being diverted for military production. In such a comparison, due account should of course be taken of the amounts of chemicals imported, which should be added to the total production figure, and also of the amounts exported, which may notionally be included under consumption. Some proportion of output may be placed in storage if there is temporarily no market for it, or for other reasons. On the other hand, consumption may include chemicals which had been produced before the beginning of the period under study. Bearing these circumstances in mind, any discrepancy between the volume of production and the volume of consumption should be carefully studied. When no data are available on the consumption of a particular chemical, it would be useful to analyse data on the production of substances in whose manufacture this chemical is used as an initial or semi-finished product. If one knows the approximate amount of the chemical needed for the production process, one can thus calculate the total amount of the chemical consumed. At the same time, it is of course essential to remember that the rate of use of one and the same chemical may differ widely from enterprise to enterprise, depending on the level of industrial technology, the degree of mechanization etc.

Limitations on patenting

It would be expedient, as a measure to increase control over scientific research, to prohibit the patenting of chemical substances, weapons, equipment and means of delivery which are banned by the convention, that is, to stop issuing patents and to cancel existing patents in this field. This measure, which is in keeping with the provisions of article IV of the draft convention submitted by the socialist States, would considerably lessen the incentive for further research in the field of chemical means of warfare.
INTRODUCTION

I. SEISMIC IDENTIFICATION PROBLEMS AND DIRECTIONS FOR FURTHER RESEARCH

A. The problem of unidentified events
   1. Focal depth determination
   2. Low Rayleigh-wave/P-wave ratios ("anomalous" events)
   3. Other discriminant criteria
   4. Theoretical research models

B. The problems of evasion
   1. Low coupling media
   2. Cavity decoupling
   3. Interfering events
   4. Simulation of seismic signatures of earthquakes by multiple explosions

II. A PROGRAMME FOR THE ACQUISITION OF A HIGH-QUALITY DATA BASE

A. New data requirements
B. Seismic research observatories
C. New long-period arrays
D. Improved capabilities for research
E. Unmanned seismic observatories
F. Communication systems and data analysis
INTRODUCTION

In its continuing contribution to the work of the Conference of the Committee on Disarmament, the United States presented a paper in August 1972 (CCD/388) outlining progress in seismic verification research, certain residual problems preventing seismic verification down to low magnitudes, and some of the directions of research requiring investigation to assist in the solution of these problems. The present paper gives a more detailed treatment of critical aspects of these verification problems and outlines the programme of research which the United States is currently undertaking to help solve these problems.

I. Seismic identification problems and directions for further research

In the United States presentation of last summer (CCD/388), some of the problems in seismic verification, namely, anomalous events, interfering events, and evasion, were briefly described and documented. In the present paper, we will give a broader discussion of these problems, indicate current ideas on approaching them, and show how they influence the present United States research programme. The discussion highlights the directions of research necessary to address these problems, including the deployment of new installations, for the acquisition of a more comprehensive data base than now exists.

We shall approach this discussion along two avenues.

The first discusses "The problem of unidentified events", which arises from a combination of the physical properties of the solid earth and our ability to detect signals with enough signal-to-noise ratio to discern useful diagnostic information. The second discusses "The problems of evasion", which arise from situations in which detection can be prevented or identification confused.

A. The problem of unidentified events

It is unlikely that any seismic network will be able to identify by quantitative criteria all of the earthquakes detected by it. These failures will arise for a variety of reasons. Included among these reasons are the following.

1. Situations arise where, based on data available from a specific network, (a) there are inadequate data available to establish depth of focus, and (b) comparison of amplitudes of 20-second Rayleigh waves and 1-second body-waves yields anomalously low $M_s$ values (relative to $m_b$) for shallow focus earthquakes, that is, values very near those of explosions.

Ibid.
2. These and other criteria, such as first motion, complexity, amplitude of Love waves relative to $m_b$, ratio of Rayleigh waves to Love waves, and spectral content of Rayleigh and Love waves, fail to yield unambiguous results. This is due in most cases to signal-to-noise problems, but is in some cases related to either the source characteristics themselves or to the interplay of source characteristics and the geographical distribution of the detecting stations. In some cases it could also be due to incomplete analysis.

3. Low signal-to-noise ratio (including interference from seismic waves of other events) is probably the most important factor contributing to unidentified events because it prevents the acquisition of critical identification evidence. It may appear as a limitation on capability to establish depth of focus, or as an inability to detect surface waves for earthquakes which actually have $M_{s-m_b}$ values well within the earthquake population. Noise is also the ultimate limiting factor in detecting events.

For a better understanding of the impact of these factors upon the capability of a verification network, each of them is discussed in more detail below.

1. Focal depth determination

A seismic event whose depth of focus is known to be below the maximum feasible depth for drilling a hole is by definition an earthquake. Experience shows that the majority of earthquakes fall into this category. Only a small fraction of earthquakes, and probably few above $m_b$ 4.5, occur at depths at which it is practical to emplace nuclear devices. Furthermore, since depth may be determined from short-period P waves alone, which are the most easily detectable signals at great distances from the epicentre, depth determination is the most effective and relevant identification method for low magnitude earthquakes when recorded by current long-range networks.

Important as focal depth determination is in its own right, it should also be remembered that it is closely related to, or even an essential ingredient in, other criteria, such as the $M_s$-$m_b$ technique since it has been found that surface wave generation is highly dependent upon depth of focus. The predicted $M_s$ changes with depth for average earthquakes mechanisms are illustrated in table 1. An extreme case is that of the strike-slip earthquake, which is predicted to have $M_s$ values 0.3 magnitude units lower than the average values shown.

![Table 1](image)

The amplitude of surface waves as a function of depth of focus, as predicted by theoretical models, averaged over several earthquake mechanisms

<table>
<thead>
<tr>
<th>Depth of focus (Km)</th>
<th>Difference in $M_s$ relative to a zero depth earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-0.55</td>
</tr>
<tr>
<td>30</td>
<td>-0.30</td>
</tr>
<tr>
<td>45</td>
<td>-0.65</td>
</tr>
<tr>
<td>65</td>
<td>-0.85</td>
</tr>
<tr>
<td>85</td>
<td>-1.20</td>
</tr>
</tbody>
</table>
Calculations are based on double-couple point source models in a continental structure and the $M_s$ values are based upon the measurement of Rayleigh waves of 20-second period. $M_s$ values shown are averages of several models of different dip and slip angles, and all azimuths.

A variety of procedures exist for establishing depth, some being much more widely used today than others because of the nature of normal data sources, not necessarily because of their greater intrinsic capability to establish accurate depths. The procedures currently employed are described below.

1. **Depth from P travel times.** The technique most commonly used today is based on observed arrival times of the P phase at a number of seismological stations in conjunction with an observed travel-time curve. When numerous stations well distributed in range and azimuth have observed a seismic event, depths accurate enough for identification purposes may be obtained by this technique. However, when only a few stations observe a seismic event, as is often the case for low-magnitude or mixed events, the combined effects of heterogeneities within the earth, poor azimuthal and distance distribution of the detecting stations, and low signal-to-noise ratios, can lead to large errors in calculated depths. Improvement in capability of this depth determination technique depends upon increasing the signal detection capability of stations in the network, which is one of the features of our current programme of deploying improved seismic stations, and upon obtaining improved travel-time calibration.

2. **Depth from reflected P and S waves.** Another commonly used technique today is based on detection of the P and S phases reflected at the surface of the earth near the epicentre, that is, the pP and sP phases. If well observed at several stations over a wide range of epicentral distance, accurate depths are obtainable by this technique, although there are also limitations in its use by a verification network. Many earthquakes do not generate clear pP or sP phases and hence improvement in station detection capability is not likely to help significantly in such cases. Several stations at different distances must observe the phase to insure that it is correctly identified as pP. Also, for depths of perhaps 30 kilometres or less, the interval between P and pP may be almost constant and hence the pP phase may be indistinguishable from the P phase of a second appropriately timed seismic event. Further work on means for improving signal-to-noise ratio and for P coda suppression is the most promising avenue of research on this technique currently being pursued.

3. **Travel-time calibration using data from large events.** A refinement of the P-wave technique is based on calibrating P arrival times of small events by use of the data of large widely recorded events. This technique accurately compensates for scatter in travel times caused by heterogeneities in the earth if the depth of the large events are known independently from other seismic data. Analysis of available data indicates that calculated depths with standard deviation of about 20 kilometres from depths calculated by pP are possible by use of this technique with teleseismic data. For optimum use, this method requires a set of "master" earthquakes no further apart than about 2° (220 kilometres) throughout all seismic areas of interest, and probably closer along major crustal and upper mantle discontinuities such as those associated with plate boundaries. Insufficient data, or mistiming of arrivals due to low signal-to-noise ratio, or inadequate depth resolution whereby events of a depth of 50 kilometres may even be classified as possibly of zero depth, may limit the utility of this technique. Work is needed to extend calibration efforts to new areas, and to relate the structural and tectonic features of the crust and upper mantle to observed deviations from calibration events.
4. Use of correlated S and P phases. A classical method of determining focal depth starts with an estimate of the time of origin of an earthquake as calculated from the time interval between S and P body waves following the same path. In principle, observation of time of arrival of S and P at a single station is adequate to determine an accurate time of origin in regions where the ratio of velocities of S and P is known. The elapsed time between this origin and the observed P wave arrivals at a given network of stations may then be used to determine depth, since the time required for P waves to travel through the earth to distant stations decreases as focal depth increases. This technique is valid in some cases even for relatively poor azimuthal distribution of recording stations and strong regional source bias. In principle, it can achieve depth estimates with accuracy of 10 kilometres or less using single station S-P observations and 5 kilometres or less with multistation observations. One limitation lies in the fact that S waves from events below about $m_D 4.0$ may have such low signal-to-noise ratios that their arrival times may not be determinable with accuracy beyond about 1,000 km. In some cases this problem may occur for events of $m_D 4.5$. For events smaller than $m_D 4.0$, shorter distances than 1,000 kilometres would be required to obtain accurate arrival times. Another limitation results from the diffuse beginning of the S wave from earthquakes in some regions, which prevents determining the arrival time of S with accuracy in the presence of the continuing P-wave coda. In addition, research appears to be needed on the effect of recently reported changes in the velocities of P and S (and hence the inferred focal depth), which appear to change significantly with time as a result of changes in the regional strain preceding a large earthquake.

5. Spectral techniques. A technique which appears promising is the use of the spectral data of Love and Rayleigh waves. Analysis by several authors of the predictions of current theoretical source models and limited attempts to use these models for predicting depths of focus of earthquakes indicate that extensive investigation of this technique is warranted. Figure 1 shows Love and Rayleigh wave spectra calculated for strike-slip earthquakes at depths of 0, 10 and 45 km.

Note that the general level of the Rayleigh-wave amplitude decreases more rapidly with depth than does the amplitude of Love waves, and that the general shapes of the spectra, if smoothed over bands several seconds wide, also change materially with depth. The relative general levels and shapes of Rayleigh-wave and Love-wave spectra, therefore, provide a basis for estimating focal depth. Notches and other fine details of the spectra, which have previously been suggested as a basis for depth determination, do not appear to be essential. Also note that the figure suggests that the technique is most sensitive for very shallow depths where the information is most needed. Limitations on its use are effects of earth inhomogeneities on observed spectra (multipathing effects primarily) and possible need for multistation broadband (10-50 sec.) observation of both Love- and Rayleigh-wave spectra. As will be described later, a major part of the United States research programme is directed at acquisition of broadband long-period data for both Love and Rayleigh waves. Only as yet uncompleted analysis can address such questions as the following:

(a) At what ranges can the required data be observed as a function of source amplitude, path of propagation, and wave type?

(b) How serious are multipathing effects?
(c) Will present data processing techniques be adequate to solve the multipathing problem?

(d) How generally applicable is the technique?

2. Low Rayleigh-wave/P-wave ratios ("anomalous" events)

As previously shown in document CCD/388, some earthquakes occur under conditions where the available data are insufficient to establish the focal depth conclusively and where the surface-wave magnitude ($M_s$) is much lower than the average expected of shallow focus earthquakes of comparable P-wave magnitude ($m_P$). Such events have been called "anomalous" earthquakes. They are sometimes termed "explosion-like" because they cannot be distinguished with confidence from explosions on the basis of the available seismic data on focal depth and the $M_s:m_P$ criterion. This does not imply that the source mechanism is actually "explosion-like". There is evidence on some of the larger so-called "anomalous" events of radiation asymmetries characteristic of faulting as well as of focal depths of tens of kilometres. Such characteristics could be exploited for seismic identification if adequate data were available.

A number of possible causes of "anomalous" earthquakes have been suggested. These and suggested research approaches will be described in the following paragraphs.

Possible causes of "anomalous earthquakes". One suggested explanation is that stress relaxation in the rock mass at the time of the earthquake is so rapid compared to the period of the seismic signals as to simulate spectrally the source-time function of explosions, thus leading to $M_s:m_P$ values like those of an explosion. Source-time functions having equal spectra will produce similar $M_s:m_P$ values averaged over all azimuths whether the source symmetry is that of an explosion or of an earthquake. It may be that so-called "high-stress drop" earthquakes have source-time functions tending in the direction of explosions, though earthquakes calculated to have high-stress drops are not "anomalous" in the sense of being indistinguishable from explosions by $M_s:m_P$. Identification by such criteria using only long-range data would be limited to relatively large events because of the requirement for data at adequate signal-to-noise ratio at sufficient stations. On the other hand, events with high enough stress drop to produce anomalous events simply may not exist and other explanations must be necessary.

Another suggested explanation of the cause of anomalous earthquakes is based on the effect of focal depth on Rayleigh-wave generation. As was mentioned earlier in the section on focal depth, Table 1 indicates the predicted relative $M_s$ values as a function of depth averaged over all azimuths for the average for several earthquake models having strike-slip and dip-slip motion on both vertical and dipping faults. The earthquake model assumed a point source and an identical flat spectrum. It will be seen from figure 1 that focal depths greater than about 45 kilometres are sufficient to produce $M_s:m_P$ ratios well below the mean for shallow earthquakes. As previously noted, strike-slip earthquake mechanisms tend to produce even lower $M_s:m_P$ ratios than for the average earthquake.
The table also shows clearly the importance of determining focal depth: not only would the "anomalous" event be identified by depth, but the weak Rayleigh waves would be explained. This could in part explain some of the low points of figure 5 in the United States working paper CCD/388. Approaches to the solution of the depth problem were discussed earlier.

Other factors that may contribute to the anomalous event problem are regional propagation effects that may bias \( m_B \) values high or \( M_S \) values low. Data published by several authors indicate regional perturbation of \( m_B \) values of more than half a magnitude, approaching a full magnitude in some places. Such effects may be most confusing without regional calibration, but techniques exist which appear to be adequate for removing major effects. A variety of path effects have been observed, and techniques have been developed which can minimize these effects. However, they do require extensive data and extensive analysis.

A further possible cause of low surface wave energy being detected at a given station lies in the azimuthally dependent patterns of radiation from earthquakes. Radiation patterns of Rayleigh waves from strike-slip earthquakes display zero-value amplitude minima in four directions (figure 2) so that, when identification is based upon only a few observations, it would be relatively easy to get a mean \( M_S \) value distinctly less than the azimuthal mean value of table 1, causing the event to be considered "anomalous". Fortunately, these Rayleigh-wave minima are azimuthally colocated with Love-wave maxima. This is yet another reason for developing a high capability to detect Love waves.

3. **Other discriminant criteria**

The criteria discussed here have various reasons for their limited utility. The first motion criterion requires probably the highest signal-to-noise ratio of any criterion. In practice, we find that it is effective at long ranges chiefly for events above about \( m_B \ 5.0 \). Clear first-motion data can be observed at short ranges (a very few degrees) for events of \( m_B \ 4 \ l/4 \) or so, but the network required is prohibitively complex. Another problem is that many Eurasian earthquakes have radiation patterns giving rarefactions only in very restricted azimuths and ranges. Consequently, even the detection of numerous clear first motions may be insufficient to distinguish such earthquakes from explosions.

Although the complexity criterion may be improved by current investigations, its susceptibility to simulation and its dependence upon high signal-to-noise ratio throughout the P coda limit its utility for seismic identification.

Diverse long-period criteria, such as spectral criteria and ratio of Love to Rayleigh waves, are all indicated by theoretical arguments to be of great use, but have not yet been adequately investigated. Because adequate data are not yet available to estimate their general utility and because of the possible limitations on their use imposed by a somewhat heterogeneous earth, no conclusions can be drawn as to how useful any of these concepts will be for seismic identification. Present research plans are designed to provide such data.
4. Theoretical research models

From the preceding, it is evident that more work is needed on understanding the fundamentals of seismic wave generation and propagation. Extensive work on developing analytical models of earthquakes and explosions consistent with observations has been done in the past by many investigators from several countries. This is an area of research where each new paper expands the level of understanding and analysis reached by earlier efforts, and the nature of the improvement required in the analytical models is found only after acquisition of laboriously and expensively obtained empirical data.

Efforts to describe earthquake sources theoretically have resulted in two basic models. One is generally referred to as the dislocation model, and the other a stress relaxation model. Without going into detail, a dislocation model appears to predict a flat source spectrum at low frequencies, while a relaxation model predicts either a peak or a flat spectrum at low frequencies depending upon certain conditions of stress change. Similarly, despite comprehensive work on the subject over several years, it is still uncertain whether explosions can be represented by a single source function, or whether the spectra of different explosions can be quite dissimilar, depending in complex ways upon geological medium, water content of the medium, yield and other parameters. The practical implications for our purposes is that criteria such as that based on $M_b$ vs $m_b$ cannot be extrapolated with confidence outside of the directly observed magnitude range without better understanding of both earthquake and explosion sources.

As also pointed out above, regional source and propagation factors may strongly perturb critical identification parameters. Though most of these phenomena are well understood in principle, adequate calibration of these effects in numerous critical areas has not yet been achieved. The consequence at present is that seismic spectra may be distorted by self-interference effects of multipath propagation, or magnitude estimates may be in error from use of inapplicable amplitude-distance corrections. Further investigations of propagation effects are needed to address these problems.

B. The problems of evasion

Seismic detection and identification thresholds as usually discussed are implicitly based on current nuclear testing practices, rather than on evasive testing practices which might be employed in the future in an attempt to prevent recognition that a test had occurred. Several techniques have been suggested for evasive nuclear testing. While limited experimental evidence, as well as theoretically based calculations, continue to indicate that these approaches are feasible in principle, none has been fully evaluated. Our research programme attempts to determine the impact of the requirement to deter evasive testing upon the design of seismic networks for surveillance.

Table IX of document CCD/388 indicates evasion possibilities as high as 100 kilotons against an excellent teleseismic network. Beyond this, it seems clear that no feasible network depending upon long-range detection of all data will be able to achieve a really high capability against deliberate evasion at yields of 20 kilotons or less. As a corollary to this, data obtained at less than teleseismic distances would be needed to combat evasion schemes to lower levels than this. In this context, we will briefly discuss the seismological factors involved in some of the evasion scenarios that have been suggested.
Table 2

Estimated magnitude ($m_p$) from full and partially decoupled shots relative to shots in hard rock

<table>
<thead>
<tr>
<th>Degree of decoupling</th>
<th>Approximate yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 KT</td>
</tr>
<tr>
<td>Full decoupling (x75)</td>
<td>3.4</td>
</tr>
<tr>
<td>Partial decoupling (x10)</td>
<td>4.3</td>
</tr>
<tr>
<td>Hard rock (x1)</td>
<td>5.3</td>
</tr>
</tbody>
</table>

1. Low-coupling media

As previously documented, explosions in dry alluvium result in seismic signals which are in the body-wave magnitude range 2.9 to 3.6 for explosions of 1 to 10 kilotons. The availability of dry alluvial deposits thick enough to contain such explosions and prevent highly visible surface effects probably limits the use of this technique in most parts of the world to explosions in the 1-2 kiloton range.

2. Cavity decoupling

The two experiments conducted to date on large cavity decoupling, one in a mined salt cavity (COWBOY) and one in an exploded salt cavity (STERLING), yielded decoupling factors of 75 at periods of 1 second. Theoretical considerations suggest factors as high as 150-200 would be attainable under more favourable conditions. Table 2 illustrates the seismic magnitudes which might be generated using decoupling factors of 75 and 10 with a range of yields. Thus, a 50-kiloton explosion decoupled by a factor of 75 is estimated to drop in magnitude from 5.3 to 3.4, a 10-kiloton explosion from about 4.7 to 2.8 and a 1-kiloton explosion from about 3.8 to 1.9. Though the feasibility of building salt cavities large enough to decouple 10 kilotons has not been demonstrated, there is little doubt that cavities adequate for decoupling yields of 1-5 kilotons can be constructed. Extensive empirical data and network analyses make it clear that it is not feasible to develop the capability to detect, on a multistation basis, events decoupled by the indicated amounts using a network deployed at teleseismic distances. Thus, evasion at yields of at least several kilotons seems feasible against detection by such a network.

Concepts for achieving 10-fold decoupling in widely distributed hard-rock terrains have been suggested, such as small-hold partial decoupling and energy-absorbing liners in the cavities. Such decoupling would give an $m_p$ of about 3.7 for 10 kilotons, 3.4 for 5 kilotons and 2.8 for 1 kiloton. Yields of several kilotons
would be possible against a very high quality teleseismic network, and against the present WWSSN, 25- to 50-kiloton explosions decoupled by a factor of 10 would be undetectable. These yield thresholds are based on the assumption of normal microseismic noise.

3. Interfering events

We have mentioned previously that a major cause of unidentified seismic events is signal amplitudes too low to be seen or accurately measured in the presence of seismic noise. This noise may be normal microseismic noise, which establishes the generally given detection thresholds of a network. Much more important in some respects, however, is the abnormal "noise" level caused by the seismic waves of large earthquakes. For example, a one-month study of data obtained at four widely separated three-component long-period stations indicates that the surface waves of about 10 per cent of shallow-focus earthquakes of $m_b$ 4.0 were undetectable at any of the four stations because these waves were mixed in those of larger earthquakes. This percentage can be reduced by arrays or by close-in stations in certain areas, but it is clear that, even with sophisticated analysis and extensive networks, mixing will be one of the more difficult problems. The fundamental problem here is that this significant set of unidentified earthquakes creates a "noise" background against which an explosion can be lost.

The following paragraphs discuss the possibilities for evasion inherent in this situation. One case involves a large number of events of relatively small amplitude masking long-period signals only and the other involves a large earthquake completely masking both long and short-period signals.

Mixed LP, detectable SP. We are concerned in this context with the deliberate use of the technique to create an unidentifiable, though detected, event. For illustration of the scope of this problem, consider figure 3 and table 3. Figure 3 illustrates the general quantitative parameters of relevance in making a preliminary analysis of this problem from the point of view of the detection network. Consider surface waves of a major earthquake ($Q$) propagating to station ($S$). Surface waves of the event to be hidden ($E$) are presumed to be so timed in their arrival at ($S$) that they arrive during the surface wave coda of ($Q$). An average ($Q$-$S$) epicentral distance of $90^\circ$ and the Gutenberg $M_S$ recurrence relationship for world-wide seismicity have been used. For example, table 3 indicates that, for an $M_S$ 4.0 signal from $E$ recorded at $15^\circ$, timing of the $E$ signal so that it arrives at $S$ after $Q$ coda has decayed to 1/10 its peak amplitude would achieve effective hiding when requiring only an $M_S$ 6.1 signal from $Q$, thus implying that hiding could be achieved approximately 90 times a year. A similar number of opportunities exist from an $M_S$ value of 3.5 from $E$ recorded at a $5^\circ$ distance. Detailed analysis of this problem confirms the general conclusion of this simplified presentation that surface-wave codas of earthquakes are so long and of such amplitude that effective recording of the long-period data from $m_b$ 4.5-5.0 events by a teleseismic network can be readily prevented by technically feasible evasion scenarios.

Mixed SP and LP signal. Due to the short duration of short-period P-wave codas, this technique relies on either the massive swamping of all detectors world-wide due to major but infrequent earthquakes or on the ability to detonate an explosion within a few tens of seconds after a large earthquake occurs in the vicinity of the test location. In either case, hiding opportunities of this type are far fewer than for hiding of only long-period waves in a smaller earthquake, and require operationally much more complex evasion scenarios, although the tester might have greater time to carry out the testing procedures.
Table 3

The number of opportunities per year for hiding the surface waves of an explosion in the coda of an earthquake as a function of distance, sensor system directionality and size of explosion surface wave

<table>
<thead>
<tr>
<th>Type of seismic installation</th>
<th>Magnitude of Hidden explosion (M_s)E</th>
<th>Angular distance of hidden explosion to detecting station ( \Delta )</th>
<th>Minimum magnitude of masking earthquake (M_s)E</th>
<th>Approximate number of opportunities per year for masking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single omnidirectional seismometer</td>
<td>3.5</td>
<td>5</td>
<td>6.1</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>5.6</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>5</td>
<td>6.6</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>6.1</td>
<td>90</td>
</tr>
<tr>
<td>Long-period array with x 10 directional</td>
<td>3.5</td>
<td>5</td>
<td>7.1</td>
<td>10</td>
</tr>
<tr>
<td>discrimination</td>
<td></td>
<td>15</td>
<td>6.6</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>5</td>
<td>7.6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>7.1</td>
<td>10</td>
</tr>
</tbody>
</table>

Assumptions:

(a) \( M_s \) computation with distance given by \( \log A/T = M_s - 1.66 \log \Delta \) \( \Delta \geq 25^\circ \)

(b) Ratio of the maximum amplitude to coda amplitude at time of arrival of surface waves from explosion is 10.

(c) Distance of masking event to detecting station, \( \Delta \) \( \theta = 90^\circ \) (see figure 2).

(d) Recurrence curves for frequency of events at various surface-wave magnitudes as given by Gutenberg.
The successful execution of a scenario based on this general idea would achieve, of course, complete hiding of the occurrence of a seismic event and thus of any seismological clue that clandestine testing has occurred.

4. Simulation of seismic signatures of earthquakes by multiple explosions

The degree of credibility of this scheme depends upon the detailed equipment, data sources and data analysis of the verification network. If obscuring of first motion and simulation of complexity and $M_S:m_b$ are sufficient to provide an adequate simulation of an earthquake, then evasion by this approach is quite simple to achieve. However, availability of more data, such as from close-in stations, and more extensive analysis (improved capability to establish depth of focus, multiazimuth data, analysis of Love and Rayleigh waves and spectral analysis of such data) would assist in countering this type of evasion. Because of the nature of the two problems, networks which could bring evasion by hiding-in-an earthquake under effective control could also be useful for recognition of an attempt to employ the multishot evasion technique.

II. A programme for the acquisition of a high-quality data base

The preceding review of some of the important unsolved identification problems shows that existing seismic capabilities are limited largely by purely practical problems of seismic data acquisition, as well as by incomplete theoretical understanding. These experimental and theoretical factors are, of course, intimately intertwined; the availability of more and high-quality data is not only necessary to test existing theoretical concepts, but also stimulates new theoretical ideas on earthquake and explosion mechanisms as a basis for seismic verification. While, as indicated in section I, a number of avenues are open for research directed towards reducing current problems, our over-all assessment of current limitations makes it clear that there is a real need for a significantly improved seismic data base. The improved data base will serve both as a means of experimentally substantiating hitherto purely theoretical or semi-tested discrimination methods and also as a means of solving practical problems which inhibit current research.

A. New data requirements

The conclusion must be drawn that, in order to address the problems outlined in section I, there is a requirement for certain new data. These include the following:

1. Increased body-wave sensitivity. Data at higher signal-to-noise ratio on low-magnitude events are needed for improvements in methods of determining focal depth and for better assessment of the effect of focal depth on Rayleigh-wave generation, for investigating the effectiveness of other diagnostic aids when applied to low-magnitude events and for better $m_b$ precision in discriminants such as that based on $M_S$ vs $m_b$.

2. Increased surface-wave sensitivity, that is, both for Love and Rayleigh Waves. This would permit evaluation of existing ideas on the cause of events with anomalously low ratio of Rayleigh to P waves, evaluation of the effectiveness of criteria based on Love waves (or of combined Rayleigh and Love), improved $M_S$ precision and calibration for the $M_S$ vs $m_b$ criterion.
3. **Improved signal separation by arrays and networks.** This is needed for further development of capabilities to separate mutually interfering events and to evaluate the effectiveness of event separation methods when applied on a network basis. Data processing techniques can improve signal-to-noise ratio, even under ambient noise conditions, when the microseismic noise has preferred direction characteristics.

4. **Better azimuthal distribution of sensors about sources under study.** This is essential to more precise determination of focal depths and in studies of earthquake mechanisms.

5. **High dynamic range digital data.** This is essential for effective data processing to develop techniques used to separate interfering events, and for many improved identification methods requiring computer analysis.

Seismic stations currently in operation as part of the Very-Long-Period Experiment (VLPE) can assist in providing some of the data requirements listed above. To satisfy the remaining requirements, however, the United States research programme includes provision for establishing: (a) three new long-period seismic arrays; (b) about 15 to 20 new high-quality observatories having greater capabilities than those of the current WWSSN, and (c) a seismic data management system capable of assembling, processing and facilitating access to the data by seismologists of the United States and co-operating nations. The new research stations will provide general coverage of seismic regions world-wide, but will focus to some extent on specific regions, such as the area north of the Himalayas, where seismic events with anomalously low Rayleigh waves were shown to occur (see United States working paper CCD/388). 35/ In addition to providing essential seismological data, the design and test of new stations using modern technology, advanced data transmission and processing equipment will be a significant step to realizing any future monitoring system as well as providing a high-quality research capability now. Certain important aspects of the United States research programme are highlighted below.

### B. Seismic Research Observatories (SRO)

A world-wide Standardized Seismograph Network (WWSSN) was established during the 1960s as a co-operative venture between the United States Government and many other Governments and research organizations. The broad objective was to encourage the conduct and expansion of fundamental research in the field of seismology, and thus to aid in solving problems related to the detection and identification of underground nuclear explosions. Our current understanding of seismic discrimination methods has been largely determined by data from these stations. However, this network cannot provide data adequate to resolve the seismic verification problems described above.

In the intervening decade or more since the beginning of the WWSSN programme, technology has advanced considerably. New seismometers and installation techniques have been developed and more sophisticated analysis techniques have been devised based on modern computer technology. It seems an appropriate time, therefore, to consider the upgrading of the seismic network.

Site selection criteria for the new Seismic Research Observatories (SRO) stations are of necessity more stringent than for existing WWSSN stations, because

35/ Ibid.
it is important to achieve the lowest possible noise levels. Generally, the plan calls for the colocation of the new system with certain of the WWSSN stations and those of the Very-Long-Period Experiment where conditions permit. It is anticipated, however, that to achieve the high signal-to-noise ratios required, it will prove necessary to relocate many stations away from those present locations which receive excessive short-period noise from both man-made and natural sources. One objective, therefore, will be to attempt to establish as high a quality network for detecting P waves as available resources, modern technology and local conditions permit. Selection criteria must naturally include the need for a broad geographical distribution suited to the problems under study.

A second objective will be to attempt to obtain better long-period data — particularly horizontal component data — than has heretofore been available. Previous studies have been severely limited by higher noise on the horizontal instruments than on vertical instruments, and by the difficulty of confidently resolving the transverse Love-wave component from the Rayleigh-wave component, which often overlap in time.

Within the past year, long-period data from horizontal beams of ALPA and NORSAR, and from certain VLPE stations have confirmed theoretical predictions of several years ago that Love waves will typically be as large as, or larger than, Rayleigh waves from earthquakes. These new observations have been made possible by generally better seismometer installations in quiet sites and by the use of digital data and computer processing to resolve Rayleigh and Love components.

The utility of long-period Love-wave data for the evaluation and further development of seismic discriminants, as described in section I, leads to a search for more effective ways of suppressing horizontal components of long-period noise. Various studies have shown that much of the noise at periods longer than about 30 seconds, and especially that on horizontal seismometers, results from tilting of the ground surface by atmospheric loading. Theoretical and experimental results permit relatively confident predictions that placing seismometers at depths of a few hundred metres will give the isolation from these tilt effects needed to obtain Love-wave recordings. Accordingly, we plan to install the SRO sensors at such depths.

Deep installations are, however, expensive. To make such installations economically feasible, we are supporting work on the design and development of small-diameter borehole seismometers, particularly those with broadband capability.

Economics can further be effected by reducing both operational and magnetic tape requirements by making use of an automatic event detector in the station equipment. This detector will automatically sense the arrival of short-period signals and record the event until the diagnostic parameters return to normal. It will contain a short-term memory to insure that the beginning of the signal and several tens of seconds of previous noise are not lost. Because of the lower data rate, long-period data will be recorded continuously. Both long- and short-period channels will use 16 bit gain-ranged digital format for the tape recordings, similar to that currently employed at the Alaskan Long-Period Array (ALPA).

Analogue recordings will also be a feature of the SRO stations in order to provide visual display of seismic signals. They should prove to be of considerable assistance to host country seismologists for conducting local research studies as well as operational and maintenance functions. The graphical data will continue to
be available to the United States National Oceanic and Atmospheric Administration (NOAA) for the world-wide data distribution system.

Component reliability is an important design feature of the new installations since the equipment will, in some instances, be installed in remote locations where highly qualified technicians may not be readily available. Design work on these stations will obviously assist in the future design of stations for possible test ban monitoring since the station will be automated as far as practical.

The SRO programme will follow closely the pattern established by the WWSSN programme and will be administered by the United States Geological Survey, which, on 1 July 1973, assumed the functions previously discharged by NOAA. A central file of all data will be maintained and supplied to any user at cost. Preliminary discussions have commenced with representatives of a number of countries hosting WWSSN stations.

C. New long-period arrays

The SRO programme, by itself, will make a substantial improvement in the thresholds at which both short- and long-period digital data become available. Nevertheless, our estimates indicate that further multistation long-period data will be needed for adequate studies of events with weak surface-wave signals, and particularly for developing methods for separating mutually interfering events by analysis of data from a network of seismic arrays. Consequently, our programme includes establishing three new long-period arrays. In conjunction with the existing large aperture arrays of ALPA, NORSAR and ALPA, they would provide an excellent data base for studying interfering events throughout the seismic zones of the North Pacific and Asia.

Agreement has been reached with the Government of Iran for the installation of the first array about 50 kilometres south-west of Teheran. The work will be conducted under a co-operative arrangement between the United States Geological Survey and the Institute of Geophysics of the University of Teheran. Preliminary site surveys have already been completed and it appears that this array can be substantially completed during 1974. Arrangements for the location of the other two arrays have not yet been completed.

In each case, arrays will contain seven or nine three-component sensor elements spaced 20 to 25 kilometres apart. Instruments will be arranged in a hexagonal shape with one instrument at the centre and, where conditions permit, sensors at two additional more extended locations will give added beam resolution. The sensors, located in boreholes as in the SRO programme, will have a broadband response to seismic waves from a few seconds to 100 seconds or more. Digital data format will be identical to that of the SRO stations. Each array will have a digital processor on site capable of forming beams for local analogue recording.

D. Improved capabilities for research

High-quality long-period data in digital format is presently available to us from ALPA, LASA, NORSAR and 10 VLPE stations. Detection capabilities of the arrays are well documented from extensive studies. During the past year, the VLPE
network has become fully operational and its detection capabilities have also been studied. Figure 1 shows the calculated four-station detection threshold for Rayleigh waves from the existing network of digital stations operated by, or in co-operation with, the United States. Calculations are based on measured noise levels and standard deviations in the noise, in the 17- to 23-second band. Contours show the $M_s$ value at which there is a 90 per cent probability of detecting signals at four or more stations. Noise measurements were taken from data during the period from January to March 1972, and calculations, therefore, represent the detection capability during winter months in the Northern Hemisphere.

We have taken four stations to represent the minimum number of recordings required in typical cases for research on earthquake parameters, such as focal mechanism and depth. Calculations also assume a minimum signal-to-noise ratio of 1.5 for detection, and use an amplitude vs distance relationship essentially identical to that of Marshall and Basham (1972). It will be seen that research requiring multistation digital data on events in the Northern Hemisphere is at present limited during the winter months to events somewhat larger than the detection threshold of $M_s = 3.3$ to 3.6, with a slightly lower threshold in summer.

Similar calculations for a digital network of the type that will exist after establishing new arrays and SRO stations indicate that the threshold might be reduced by $0.4-0.5 M_s$ units. Referring to figure 5 in document CCD/388, it may be seen that this should permit detection at several stations and much more sophisticated analyses of events which lie so close to the explosion population on the $M_s$ vs $m_b$ diagram that they cannot be distinguished with confidence.

Improvement expected in our capability to do research on Love and long-period S waves is more difficult to estimate because of an inadequate experimental basis for making estimates. However, studies currently under way on long-period horizontal noise as a function of depth indicate a reasonable basis for expecting that Love- and Rayleigh-wave thresholds can be made to be comparable if the proposed deep-hole installation method is employed.

E. Unmanned seismic observatories

The unmanned seismic observatory, often misnamed a "black box", is in reality a complex installation. It could logically have much common technology with the new Seismic Research Observatories. High reliability instrumentation, deep borehole broadband seismometers, and digital recording techniques are all basic ingredients of a high-quality, sensitive installation. In addition to the development of such components, we are working aggressively on those extra features which would be necessary to ensure the integrity of the seismic data derived from unattended sites. These features include tamper-resistant emplacements, an authenticating device to ensure that the data is genuine and uninterrupted, and secure data transmission to an international communications satellite system. Figure 5 shows the concept for developing the technology of an unmanned seismic observatory. We are planning to install an experimental unmanned seismic observatory to test the technology.
F. Communications systems and data analysis

The prime purpose of the seismic installations which have been described, as well as those which presently exist, is to provide high-quality data for the research seismologist.

A well-organized seismic data bank containing all the pertinent information necessary to study the characteristics of earthquakes from different regions of the world, and to apply the knowledge gained to the basic problems of seismic indentification, is also needed.

Because of the extent of the present and planned research network of high-quality single stations and arrays, the volume of digital data will be large and its management poses formidable problems. The output of all the stations must be assembled and stored at some central location where it can be retrieved on demand by the research seismologist. At some point, therefore, the large volume of data must be edited to select what is necessary for further processing. Much of this data management can be facilitated by automatic means which we plan to develop.

Data acquisition and transmission

At the present time, it is neither economical nor desirable to retrieve data from the seismic network solely by direct electrical transmission, despite the fact that it is technically feasible to do so. In the case of the single stations of the new Seismic Research Observatory programme, as well as the existing stations of the Very-Long-Period Experiment, it is more practical, and certainly more economical, to transmit data in the form of digital tapes to a central facility for pre-processing and storage. On the other hand, it is proposed to return data from NORSAR and the three new long-period arrays to a central data storage site over the INTELSAT communication satellite network. This concept promises to combine utility with economy, and will be the first experimental test of intercontinental transmission methods which may be required for detection networks of the future.

The most promising technique for satellite transmission is what is known as a broadcast mode. In this mode, data from each seismic station is accumulated in short messages or "data packets", which are then transmitted through the nearest INTELSAT earth station as the rate demands to a single wide-band channel on the satellite serving all seismic stations. The satellite, in turn, broadcasts each packet to all ground receiving stations. This mode of operation would also prove the most economical, but would be contingent upon satisfactory tariff agreements being granted by countries operating in the INTELSAT system. Tariffs for utilizing this relatively new concept tend to vary widely and, in some cases, regrettably inhibit technical progress in this field.

A key system in the communication of digital data within the United States is the ARPANET. This is a communications network which connects a number of independent computer systems and data sources so as to permit the sharing of resources between any pair of computers. Besides terminal points at many facilities in the continental United States, links have now been made to Norway, the United Kingdom and Hawaii, which permits a more comprehensive form of data exchange than at present exists.
Data storage

The key to the efficient use of large amounts of high-quality data is a mass storage device. The type of device under consideration uses film etched by a laser beam to form a memory capable of holding approximately $10^{12}$ bits of data on-line, and as much as $10^{13}$ bits off-line in a readily accessible mode. This would provide at least a year's raw data on-line, and processed material indefinitely.

In the currently planned United States research programme, processing of short- and long-period data to be held in the mass store would be controlled over the ARPANET by the Seismic Data Analysis Center (SDAC) in Alexandria, Virginia. Data files are expected to include raw data, event summaries, signal descriptions and wave-forms, as well as the results of multistation processing. Figure 6 depicts the flow of seismic data into and out of the mass storage device.

Data retrieval

An important aspect of the system is an organized and systematic procedure for the retrieval of data by research groups. For those with access to the ARPANET, requests for data would be forwarded to the Seismic Data Analysis Center, for release directly from the mass storage device.

We welcome data from seismic arrays of other nations in addition to those currently working with us. A larger total data base in the seismic data storage system will increase the research possibilities open to all investigators examining seismic verification problems. It is intended that this data base be available to any nation interested in pursuing seismic verification research.

Schedule

Initial operation of the first increment of the seismic data management system connecting LASA, the mass store, large computer facilities and SDAC is planned for the summer of 1974. The other arrays will be added incrementally during the second half of 1974 and the first half of 1975. Full operation of the system is anticipated in the summer of 1975.
Figure 1
Predicted Rayleigh and Love-wave amplitudes
as a function of period and depth of focus

The curves are for strike-slip earthquakes and assume equal source energy
and are shown for depths of 0, 10 and 45 kilometres.
Figure 2

Theoretical radiation patterns for Love and Rayleigh waves from an earthquake at zero depth when strike angle is 0°, slip angle 0° and dip angle 90°, period 20 seconds.
The configuration of detecting station, masking event and hidden event used to derive the number of opportunities per year for hiding surface waves shown in table 3

<table>
<thead>
<tr>
<th>DETECTING STATION (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIDDEN EVENT (E)</td>
</tr>
<tr>
<td>MASKING EVENT (Q)</td>
</tr>
</tbody>
</table>

$\Delta_{E}^S = E \text{ TO } S \text{ EPICENTRAL DISTANCE}$

$\Delta_{Q}^S = Q \text{ TO } S \text{ EPICENTRAL DISTANCE}$
Estimated Rayleigh-wave detection capability for a network composed of the existing 10 VLFE stations, LASA, NORSAR and ALPA.

Contours are $M_s$ values for 90 per cent probability of detection by at least four stations.
Figure 5

A conceptual view of the technology required in the installation of an unmanned seismic observatory

Communications Satellite

- Small dedicated dish antenna
- Power supply
- Transmitter
- Tamper proof vault
- Borehole
- Authenticator
- Event detector
- Seismometer
- Ground station
- Authenticator check
Figure 6

Schematic representation of a seismic data communication system for international data exchange
Introduction

The present working paper was prepared as a contribution to the forthcoming informal meeting of the Conference of the Committee on Disarmament with experts on the verification of a ban on underground nuclear explosions. Its purpose is to review, briefly, recent Swedish scientific work in this field. In particular, short abstracts are given of four Swedish scientific papers, informally distributed to delegations. The main body of the present working paper, however, consists of brief discussions of some of the subject matters listed in the Swedish working paper CCD/397 under the following headings: methods and present capabilities for verification, verification aspects of proposed treaty structures, and technical and organizational matter to be settled in connexion with a ban on underground explosions.

1. Abstracts of informally distributed papers

(a) The effectiveness of discrimination between shallow earthquakes and nuclear explosions by P-wave magnitudes at 1 and 2 Hz, by U. Ericsson, Research Institute of National Defence, Sweden and S. Miyamura, Earthquake Research Institute, Tokyo University, Japan.

Discrimination of earthquakes in Eurasia and nuclear explosions in the USSR and China was studied by a discriminant constructed from P-wave magnitudes obtained through 1 Hz and 2 Hz filters from vertical seismometers at TSK in Japan.

Discrimination between earthquakes in Eurasia and nuclear explosions in Eastern Kazakh, with estimated yields between 10 and 400 kilotons, was well comparable with the discrimination obtainable from body and surface wave magnitudes.

Discrimination of explosions on Novaya Zemlya or on the Ust-Urt plateau appeared to be much less effective. From simultaneous observations at TSK and at HFS in Sweden, it was concluded that the explanation of the difference between Eastern Kazakh and the Ust-Urt should be in these source areas rather than along the wave paths to TSK.


A catalogue of nuclear tests covering the time interval 1945-1972 has been
The catalogue is based entirely on available official announcements, information in open publications etc., collected and analysed during a decade. For each explosion, it contains information on time, location, nations, type of explosion and, where available, yield and code name.

Up to and including 25 April 1973, this catalogue provides information about 925 nuclear tests, 425 of which occurred after the signing of the partial test ban treaty on 5 August 1963. The treaty has not been followed by a decreased testing activity. The frequency of tests in the atmosphere has, however, been reduced. China and France have not signed the partial test ban treaty and are still conducting tests in the atmosphere.


In an experiment to assess some of the operational problems in the context of seismological monitoring of an underground test ban, seismic events in the USSR in 1971 have been studied.

Epicentre data from a total of 199 events, as reported by the National Oceanic and Atmospheric Administration (NOAA) in the United States, by the Institute of Physics of the Earth (MOS) in the USSR and by the Hagfors Observatory (HFS) in Sweden, are presented and compared.

Significant differences between the numbers of events reported by these three organizations were observed. Focal depth estimates reported by NOAA and MOS agreed fairly well.

Discrimination parameters obtained at HFS and the Yellowknife array in Canada were also analysed. The results support the general experience that the $m_p (M_b)$-method is the most efficient criterion and that its applicability is limited to strong events. Short-period criteria were less efficient, but could be applied to much weaker events. Combined use of available discrimination parameters identified correctly 19 presumed explosions and 134 earthquakes. For the remaining 46 events, all of which were weak and most of which were reported only by MOS, discrimination parameters were not available.

(d) Seismic source and transmission functions from underground nuclear explosions with known yields at Nevada Test Site, by O. Dahlman, Research Institute of National Defence, Sweden.

A method is presented for the simultaneous determination of the relative variation in transmission properties to different stations and of the relative differences between the source functions of closely spaced underground nuclear explosions. The model is applied to short-period data reported from 24 globally
distributed stations from 12 underground nuclear explosions with known yields at Nevada Test Site. The transmission functions vary within a factor of 10 between the stations. The relative source functions for 10 explosions in tuff and rhyolite, with yields in the range from 16 to 1,200 kilotons, are proportional to the 0.9 power of explosion yield.

The observed relative source functions agree fairly well with the relative amplitudes obtained from two theoretical source models.

2. Methods and present capabilities for verification

(a) Event detection

Since 1969, Sweden has operated the Hagfors Observatory to provide seismological data for international data exchange and for discrimination research. The detection equipment of the observatory has recently been improved and includes now three automatic detection units, one at each substation. Each automatic detector contains five seismometers emplaced in a circle with a diameter of one kilometre. The detection process exploits the amplitude, the frequency and the phase velocity of the seismic signal. The capability of the automatic detection equipment has proved to be quite satisfactory, the number of detected signals is comparable to the one detected by an experienced seismologist.

The capability to detect events depends considerably on where the events occur. The station can thus detect events on the Eurasian continent for $m_L$ (NOAA) down to somewhat below 4.5, whereas events in North America must have $m_b$ (NOAA) magnitudes of about 5 to be detected with the same probability.

(b) Event location and definition

The definition of events, by which we mean the assignment of detected signals to in space and time-located sources, is the important step by which events are pointed out for further considerations by seismologists. Such event definitions and locations are routinely made and published by agencies and institutes such as the National Oceanic and Atmospheric Administration (NOAA) in the United States, the Institute of Physics of the Earth in the USSR and the International Seismological Centre in Edinburgh. Event locations and definitions are, however, also routinely made at the Hagfors Observatory, in order to define new events in areas where other agencies may have less sensitivity. The locations are made not only with data from the Swedish array station, but also with data from stations in several other countries, obtained through an international data exchange. In one of the reports summarized above, the seismic events in the USSR in 1971 were studied. That report shows that the Hagfors Observatory located 125 of a total of 180 observed earthquakes in the USSR in 1971. The National Oceanic Atmospheric Administration defined and located 89 and the Institute of Physics of the Earth 171. Hagfors also reported 11 of the 19 explosions, all those which so far are presumed to have occurred in the USSR in 1971. The National Oceanic and Atmospheric Administration reported 18 and the Institute of Physics of the Earth did not report any of these explosions.
(c) Event identification

Short-period criteria from North American events. Different types of short-period discriminants obtained at HFS from 24 presumed nuclear explosions in southern Nevada and 33 shallow earthquakes along the North American west coast have been analysed. Discriminants utilizing detailed information about the P-wave form and the amplitude spectrum provided the best separation. Only one of the earthquakes, with a very explosion-like record at HFS, overlapped the explosion population.

Short-period identification of the North American events was, however, less effective than the identification obtained in a similar study of some 300 events in Eurasia. The P waves from North American events contain virtually no energy above 2.5 cps, whereas P waves from many Eurasian events in striking contrast have significant energy up to 4.0 Hz and above.

Variability of short-period criteria. Besides the gross short-period difference between North American and Eurasian events, the short-period discriminants also exhibit large variability. The influence of the event strength and of the focal depth is quite pronounced on the third moment of frequency discriminant, which highlights the high frequency content of the P waves. The wave form complexity, describing the duration of the P wave, seemed also to be critically dependent on focal depth. Most earthquakes below a depth of 100 kilometres give explosion-like short-period discriminants.

\( m_b (M) \) for deep events. A confident estimate of the focal depth would be an excellent seismic identification criterion. It is rather difficult, however, to estimate the focal depth and, in addition, the short-period discriminants are critically dependent upon focal depth, with deep events yielding explosion-like values. The effect of the focal depth on the \( m_b (M) \) criterion was also studied, with data obtained at NORSAR in Norway from deep earthquakes and presumed explosions in Central Asia.

It appeared that the earthquakes do not become explosion-like until below 100 kilometres.

Negative evidence. The applicability of the \( m_b (M) \)-method depends on the detection of both P waves and Rayleigh waves and is largely controlled by the detection threshold for Rayleigh waves from explosions. It appears, however, that explosions yielding only detectable P waves, can sometimes be confidently identified by using the negative evidence about surface waves. In an attempt to clarify the potential of such negative evidence, a decision theoretical model for such \( m_b (M) \) identification has been obtained and analysed.

An example, based on \( m_b (M) \) observations at HFS, showed that the applicability of the \( m_b (M) \) identification method could be extended about half a magnitude below the detection threshold for Rayleigh waves from explosions. A scientific paper, giving a full description of the model and of the numerical results, is in preparation.

Multistation identification. Swedish scientists co-operate with Canadian and Japanese colleagues in the study of identification by data from several stations.
Earlier experience (see CCD/376 and CCD/380) shows that such a combination offers significant improvements. Canadian and Swedish scientists are now jointly testing new and quite promising methods for combining multistation data.

The common Canadian-Swedish short-period data base was used in an independent Swedish study to demonstrate the increase in correct identification of explosions which occurs when complexity or third moment of frequency measurements at one station in Canada are combined with each other or with similar single or combined measurements in Sweden or vice versa. It was found that single channels of very low identification effectiveness give very high effectiveness when combined with each other.

Common data bases for multistation identification. One of the main tasks in the study of discrimination by multistation data is the establishment of significant common data bases. In an effort to find common events, for which short-period discrimination data have been obtained at HFS in Sweden, TSK in Japan and YKA in Canada, the discriminant files acquired independently at these stations have been searched for Eurasian events. The discriminants from HFS and YKA are complexity and third moment of frequency, while TSK provides magnitudes at 1 and 2 Hz. In the spring of 1973, the following distribution of individual station events and of common events was found:

<table>
<thead>
<tr>
<th></th>
<th>HFS</th>
<th>TSK</th>
<th>YKA</th>
<th>Common to HFS, TSK, YKA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of explosions</td>
<td>44</td>
<td>48</td>
<td>71</td>
<td>12</td>
</tr>
<tr>
<td>Number of earthquakes</td>
<td>314</td>
<td>63</td>
<td>280</td>
<td>12</td>
</tr>
</tbody>
</table>

This table illustrates a problem with the study of multistation identification. Canadian, Japanese and Swedish colleagues are therefore making efforts to improve their common data base.

Multistation identification appears to be a field where international co-operation promises significant improvements of global identification capabilities.

(d) Operational studies

For the discussion of the seismic monitoring of an underground test ban, it is important to study the operational aspects of the detection, location, definition and identification of seismic events. Considering the global capabilities, one must take into account not only the output of the presently reporting agencies, but also the entire joint capability of the most sensitive array stations, which today are utilized for such purposes and which would increase the number of reported events significantly. The International Seismic Month was a promising attempt to study the

36/ Ibid.
joint detection and location capability of the most sensitive seismological stations. Sweden has contributed to this study and would support more such effort. Evaluating the identification capability of seismological networks, one must consider not only the effectiveness of various discrimination criteria, but also their practical applicability. Such applicability can be measured by the strength of events to which the criterion in question can be applied. The $m_b (M_s)$ criterion is generally considered to be the most efficient one, giving very few, if any, misidentified events. The applicability of this criterion is, however, confined to rather strong events by the limited detection capability of long-period instruments. Long-period earth noise, which is one of the causes of this limitation, varies strongly from time to time, so that the applicability also varies with time. Long-period signals from interesting events can also be masked by interfering signals from other events. Studies at the Hagfors Observatory show that about one fourth of the long-period signals there are so disturbed. These interfering signals therefore constitute a serious problem. Long-period array stations can, however, in some cases separate interfering signals. In the study of the 1971 events in the USSR, the $m_b (M_s)$ criterion could be applied to about 40 per cent of the events.

Criteria based on short-period signals are generally less efficient and regionally more variable than the $m_b (M_s)$ criterion. Short-period criteria could, however, be applied to considerably weaker events and thereby to about 70 per cent of the events in the study of USSR events in 1971.

Canadian-Swedish investigations have shown that the efficiency of short-period criteria increased significantly when data from two stations were used together. The efficiency of the combined criteria was of the same order as the efficiency of the $m_b (M_s)$ criterion.

We have no specific data which could allow us a discussion of the influence on identification of various evasion methods, such as multiple explosions or explosions in cavities etc. This is, however, an important operational aspect of seismic monitoring of an underground test ban treaty.

3. Verification aspects of proposed treaty structure

(a) Definition of thresholds

Every seismological station and station network has a technical threshold below which seismic signals cannot be detected. There also exists a threshold below which event identification is not possible. This identification threshold might be different for different identification methods. Identification thresholds are somewhat higher than detection thresholds, because more information is needed to identify than to detect an event.

The level of these technical thresholds depends on the geographical distribution and the technical performance of the seismological stations and on the geophysical properties of the earth. This means that the technical thresholds could be different for different areas of the world.
It has been shown in many studies, for example, the study of source and transmission functions summarized above, that the signal amplitude recorded at different stations from one and the same event may differ by more than a factor of 10. Different methods have been proposed to compensate for these differences and to relate measurements at different stations to each other. Thus, different magnitude scales and stations corrections have been suggested.

Because of the strong variation in seismic signal properties, it is desirable that thresholds are discussed in terms of source parameters, for example, equivalent yields, rather than in terms of seismic signal parameters, such as amplitude at a reference station or magnitudes. Yield thresholds are also closely related to the testing activity. Relations between yield and seismic signal parameters at the monitoring stations for explosions in different regions should be established by the particular monitoring agencies.

4. Technical and organizational matters to be settled in connexion with a ban on underground nuclear explosions

(a) Improvements of seismological networks and stations

Experience has been obtained in Sweden from the establishment of the Hagfors array station and from its operation during four years. This type of station, with specialized automatic detection equipment, with adequately spaced recording points for event location and with both digital and analogue recording facilities, has proved to have a suitable configuration for a medium-size array station. Experience with the special automatic detection equipment has been especially good. The Hagfors array design seems suitable also for new stations, although one would have to take local conditions into account.

Throughout the years, considerable experience has been acquired in several countries on how to design, build and operate complex seismological stations. It would be important for the further improvement of global detection, location and identification capabilities to utilize this experience, when new stations are established. One way to facilitate this would be that existing array stations co-operate with interested parties to establish "sister observatories".

(b) Seismological data processing, data transmission and data exchange

At most of the seismological stations now in operation, the data are analysed at the station or at a data centre close to that station. The stations in the network proposed in the United Kingdom working paper CCD/386 37/ also have on-site facilities for preliminary data analysis. Swedish experience is that there certainly are advantages in making out the preliminary data analyses at the station or within the organization responsible for running the station. One significantly increases the performance of the station and the data quality. If, on the other hand, all data from many stations are transmitted on-line to a large computer centre, it might be very difficult for nations not having access to large

37/ Ibid.
computers and sophisticated programmes to utilize the data. To provide all interested nations with identification data, such data should be calculated at the stations and then be distributed through an international data exchange. Different stations have different capabilities to process data and, in addition, the character of the seismic waves differs significantly from station to station. It is not necessary, however, to calculate the identification parameters, for example, \( m_p (M_s) \), complexity and various spectral parameters, in the same way at all stations. Each station should rather report those identification criteria which are optimal for it, considering the instrumentation of the station and the geophysical conditions for wave transmission. It is, however, important that the definition and format of the reported data remain consistent.

The data should be made generally available through an international data exchange. Such routine exchange should include not only arrival times and amplitudes, intended for event locations and magnitude determinations, but also identification parameters from a number of key stations. This data exchange should be rather fast, using telex or WMO data channels. The exchange of record copies in one form or another should be on request only.

\[(c)\] International co-operation and organization for verification of a ban on nuclear explosions

In order to co-ordinate the data exchange and to provide all nations with preliminary identification data in an easily accessible form, it would be helpful to establish a co-ordinating data centre. Such a centre would collect not only basic data, but also derived data, such as location and identification data. It would also calculate preliminary event locations and would distribute all basic and derived data to the nations interested. The data centre would not have the task to evaluate the identification data or to make event identification, but only to provide systematically collected basic and derived data for such considerations. Event classification for political purposes would be performed on a national basis, but using available international data. To establish the reference data bases required for event identification and to establish efficient routines for the data exchange and for the operation of the centre, all time-consuming tasks, it would be advisable to establish the data centre as soon as an adequate number of nations is ready to co-operate.
The verification of a comprehensive test ban by seismological means (CCD/406)

CONTENTS

1. Introduction

2. CANSAM - The Canadian Seismic Array Monitor System
   2.1 CANSAM's immediate contribution to the verification problem
   2.2 Envisaged changes to, or expansion of CANSAM

3. Yellowknife array (YKA) short-period P-wave discrimination

4. A multinational co-operative study of the characteristics of low-magnitude earthquakes - The International Seismic Month Project (ISM)
   4.1 Canadian P-wave detection for ISM
   4.2 Canadian Rayleigh-wave detection for ISM
   4.3 An ISM-Eurasian case study using joint $M_s$:$M_b$/P-wave/focal depth discrimination
   4.4 Further consideration of the potential problem events
   4.5 Implications of the ISM-Eurasian study

5. Deterrence and false alarms - the uncertainties in the decision-making process in seismic verification
   5.1 The interpretation and extrapolation of seismic discriminants
   5.2 Discrimination results for a global suite of $M_s$:$M_b$ data
   5.3 Test ban decision-making
   5.4 A possible international seismic discrimination network

6. Conclusions

APPENDIX

References

-122-
1. Introduction

In recent years, Canada has contributed technical working papers to the Conference of the Committee on Disarmament whenever it was felt that a review of a particular aspect of the seismological discrimination research being undertaken in Canada would benefit the discussions of the Committee. The common objective of a series of such working papers has been to clarify the technical factors involved in the seismological verification of a comprehensive test ban so as to assist the political negotiating process. Since 1970, steady progress has been made and continues to be made in clarifying many aspects of the scientific problems that were virtually unresolved prior to that date.

Initially, it is instructive to review some of the questions posed in the Canadian working paper of 10 August 1970 (CCD/305) \(^{38/}\) (see item 1 in the list of references at the end of the paper), questions which arose as a result of the Canadian analysis of seismological station information requested by and submitted to the United Nations Secretary-General \((2,3)\). In particular, it is important to consider how the answers to some of these questions may have changed with greater experience and knowledge.

In document CCD/305, it was asked whether it was possible to estimate the extent of improvements in identification capabilities through guaranteed access to seismological data acquired internationally. The answer was definitely in the affirmative as a theoretical result from analysing the United Nations returns. These theoretical improvements were placed on a much clearer proved basis as a result of the Eurasian event discrimination study reported by Canada \((CCD/327 \,39/\) of 29 June 1971) \((4)\), and by numerous analyses since published in the scientific literature using only station data whose availability is guaranteed. The associated question as to whether the analysis had identified sectors of the globe for which identification capability was higher or lower than average was clearly answered in the affirmative in 1970. The degree of this global non-parity was further refined and the results presented by a Canadian scientist to the Seminar on Seismology and Seismic Arrays held at Oslo in November 1971 \((5)\).

An outstanding problem most clearly identified by these and other studies \((see, \ for \ example, \ (6))\) was the globally non-uniform capacity for the detection and location of low-magnitude earthquakes and thus a lack of knowledge of the characteristics of these events, a knowledge that is essential to the successful discrimination of lower-yield explosions. A better understanding of this problem now exists as a result of an initiative taken by the United States in their working paper CCD/388 \(40/\) \((7)\) of 24 August 1972, wherein a multinational seismic co-operative study was proposed following very closely the suggestion for data integration outlined in document CCD/327. Canadian scientists have been actively engaged in this co-operative study, and some of the contributions made and analyses undertaken will be described in the present paper.

\(^{38/}\) Ibid., Supplement for 1970, document DC/233, annex C.

\(^{39/}\) Ibid., Supplement for 1971, document DC/234, annex C.

\(^{40/}\) Ibid., Supplement for 1972, document DC/235, annex B.

-123-
Another question posed in document CCD/305 was whether further examination was warranted into the concept of international exchange of seismic data and research results. This question was, of course, anticipatory and it is necessary here simply to review some of the co-operation that has occurred in the intervening three years. As distinct from specific co-operative projects, the form of seismological data that can or should be exchanged, in particular with respect to short-period arrays, can be more closely defined: this will be discussed in conjunction with a review of progress in detection and analysis on site at an array given in a later section of the present paper.

The voluntary international exchange of seismic data for purposes of earthquake hazard reduction has long traditions which have benefited all research related to the seismological verification problems. Similarly, there has been a long tradition of exchange of both research personnel and research results in this geophysical discipline. Thus, document CCD/327 drew upon results obtained from a Canadian and a British scientist working together. More recently, as a result of stimulus from the Conference of the Committee on Disarmament, measures of bilateral and multilateral co-operation have developed as concerted efforts to solve some of the outstanding verification problems. An example of the success of these measures was presented to the Committee last year as a joint Canada-Sweden working paper (CCD/380 40/ of June 1972) (8). This was an experiment to assess the improvement achieved in short-period P-wave discrimination, when employing two widely separated array stations, over that achieved by either station alone. Such co-operation is continuing and is reviewed in a later section of the present paper. In attempting to expand this type of co-operation, a conference of scientists from Japan, Sweden and Canada was held at Tokyo in June 1972 to reach agreement on practical steps to improve trilateral co-operation. The results of this conference were reported to the Committee as a tripartite working paper by the three countries concerned (CCD/376 40/ of June 1972) (9); the conference led to a fruitful exchange of data and research results among the three parties within the last year.

The United States working paper (CCD/388) provides a focal point for further technical discussions. It reviewed the progress achieved on United States research objectives, delineated clearly some remaining problems and introduced the multinational co-operative study mentioned above. The same paper also focused sights of the Conference of the Committee on Disarmament firmly on future progress: what future facilities, data co-operation, methods etc., can achieve the desired objectives? As progress is made, the requirements for the future change. In a final section, a Canadian technical assessment of this "future" is outlined. By presenting a summary of research which attempts to focus on the decision-making power of the seismic discrimination process and on the envisaged interaction between the seismological results and the verification requirements, one practical concept of verification involving international co-operation is outlined; it is believed to be economical, practical and of proved and defined power.

2. CANSAM - the Canadian Seismic Array Monitor System

The impressive capabilities of the expensive, large-aperture seismic arrays, such as LASA and NORSAR, are now well established by American and Norwegian studies.
However, to attain the optimum possible verification threshold on a world-wide, or at least northern hemisphere, basis at realistic cost levels, it has been suggested that the existing large-aperture arrays be supplemented by a number of high-quality, single seismic stations and/or medium-aperture arrays. In document CCD/327 and elsewhere, data integration of P-wave arrival information from the best existing stations and medium-aperture arrays was urged. In document CCD/296 of 28 July 1970 (10), the United Kingdom discussed a world-wide network of about 26 array stations with on-site processing followed by data collation and further analysis at a larger centre. Document CCD/388 discussed some of the problems involved in collecting and correlating data from a network of stations at one or more central analysis centres using modern satellite communication systems, and a digital communications network within the United States. The essential difference between the two approaches lies in the fact that the systems envisaged in United States working paper CCD/388 are technically more complex, because the concept requires not only real-time detection and location of events, but computer storage virtually instantaneously of all or at least much of the data.

In Canada, a programme of medium-aperture array development has been under way for some years: with the decrease in costs of small computing facilities, a further step in development is now under way with the objective of demonstrating the feasibility and estimating the reliability in an isolated area of operating economically medium-aperture arrays with some automated on-site data processing, which might serve as a prototype model for more extensive world-wide deployment in a comprehensive test ban situation.

In 1962, a United Kingdom-type medium-aperture short-period seismic array (code-named YKA) was constructed near Yellowknife, N.W.T.: the initial electronics hardware was supplied by the United Kingdom and the remaining facilities and operation by Canada. Short-period seismic data from 19 seismometers laid out in an asymmetric cross of 22.5-kilometre aperture are recorded in analogue form at the array site. Data reduction using digital computers has been possible since 1965, but has been restricted to non-real-time processing at a research facility in Ottawa, at least weeks, and sometimes months or years, after the signals were recorded. Repeated experiments have simulated on-line operation only over relatively short-time intervals. These experiments and achievements have been reported to the Conference of the Committee on Disarmament on previous occasions.

In recent years, a long-period tripartite array has been added, and the system rebuilt, improving the electronics and installing a modern two-way radio-telemetry system, thereby eliminating the transmission of data by cables prone to breakdown. The field reliability and economy achieved in a harsh northern environment in this Canadian development are excellent.

Based on experience with delayed real-time digital processing in Ottawa, a stand-alone, real-time digital array processing system has now been developed based on a small, general-purpose digital computer and associated hardware, and is being evaluated in the Ottawa laboratory. Later in 1973, this system will be moved to the array site.

41/ Ibid., Supplement for 1970, document DC/233, annex C.

-125-
Briefly, the total system will be composed of an array-instrumentation monitor, short-period beam former, event detector and event data logging equipment. The output from the processing system includes a hard-copy event bulletin listing detection parameters related to epicentral region, arrival time and event magnitude. A digital tape is written, containing a duplicate of the bulletin information and the unprocessed broad-band short-period data for all channels for the period of the event. Future research will be directed towards the inclusion of automatic discriminant programmes which are envisaged to operate in a background mode on selected events only. The system is flexible enough so that future requirements for on-line connexion to world-wide or regional data centres will be possible. The digital tape could, as well, be easily duplicated for international exchange purposes.

2.1 CANSAM's immediate contribution to the verification problem

The multinational experiment referred to earlier has demonstrated not only the power of event data integration, but also the logistic problems in collecting and correlating event detections from the currently existing net of high-quality stations and arrays. If a real-time, or near real-time, event detection threshold near the proved off-line capabilities is desired, then some way must be found to collect and correlate detection data on an on-line basis. One method was described by the United States (CCD/388), but it remains to be seen whether an on-line, long-distance, round-the-clock transmission of a vast quantity of raw data is really a necessity, or whether a much more limited exchange of data will suffice.

In the past, the Yellowknife array was a research and development tool and it was not possible to contribute its data to the international data-collecting agencies on a continuing operational basis. However, duplicate tape recordings have continued to be made of YKA data for United Kingdom research purposes. The special-purpose, digital processing system installed at Ottawa in 1967 could not handle all the array data and on-going research projects with one-shift support on regular working days. However, when CANSAM is moved to Yellowknife later in 1973, the situation will be transformed if operational reliability can be assured.

The first benefit of CANSAM for the international seismological community will be an additional number of low-magnitude phase readings extracted from the automated YKA bulletin, which will reach the NOAA earthquake centre currently integrating international data on events. The observations can be transmitted within the framework of the customary Canadian contributions from the Canadian seismograph network. Similar distribution of YKA detection bulletin to other interested parties will be possible. Moreover, it will become much easier to satisfy requests for YKA digital raw data, since edited digital tapes of all detected events will be readily available. Finally, the new system will give new impetus to seismological discrimination research in Ottawa, since the readily available digital data will free much time on the special processing system for detailed off-line studies.

2.2 Envisaged changes to, or expansion of, CANSAM

Should the need for an extended on-line, long-distance data exchange become more pressing, the present CANSAM configuration will prove to be quite adaptable.
Although the necessity or benefit of moving many kilobauds of raw data for processing in a large computer elsewhere is unproved, the present system could be down-graded to a simple data-acquisition system and communication interface. A financially more appealing alternative would be the on-line transmission, possibly over dialled lines, of reduced detection data to a world data centre. Possibly only unidentified events in geographic regions of interest would qualify for transmission. On a slightly more sophisticated level, the data centre would be able to query the array processor, to initiate a repeated search for an event during a given time window, or transmit the raw data for such an interval to the centre. This degree of sophistication would, of course, require much larger data-storage facilities than are now available for CANSAM, and would probably also require dedicated, expensive communication channels.

In conclusion, the CANSAM system appears to be sufficiently flexible to make an important contribution to any serious operational verification system under active discussion: it will provide much needed operational experience for either mode. In the event that financial and/or policy constraints on a seismological verification network dictate maximum economy in view of the established limitations of the seismological discrimination method, the CANSAM development without a real-time super data exchange system may provide an essential prototype.

3. Yellowknife Array (YKA) short-period P-wave discrimination

In the past decade of research into methods of seismological discrimination, groups in a number of countries, notably the United Kingdom, United States of America, Sweden, Japan and Canada, have been pursuing the development of an effective short-period P-wave discriminant. The inherent value of such a discriminant is that it may be applied close to the P-wave detection threshold, rather than having to rely, for example, on Rayleigh wave observations to provide $M_S:mb$ discrimination at a generally higher-magnitude level. Furthermore, the method becomes more effective for lower-magnitude events for technical reasons related to the pass-band used, and it may lend itself to on-site automation in a CANSAM-like development. The results that have been achieved with short-period P-wave discriminants have not received their due attention, perhaps because of the initial failure to devise a "perfect" discriminant: thus, it was discouraging to find, using techniques in fashion a few years ago, that 20 per cent of explosions were indistinguishable from the earthquakes in mixed populations. Considerable progress has since been made.

Recent improvements in techniques of short-period P-wave discrimination, coupled with recently demonstrated failures of the $M_S:mb$ criterion in certain Eurasian source regions, have left the two discrimination methods at present on a nearly equal footing with respect to their general utility in the verification process. A brief review of the history and achievements in short-period P-wave discrimination up to 1972 was presented to the Conference of the Committee on Disarmament last year as a Canadian/Swedish working paper (CCD/380). As will become evident in later sections of the present paper, P-wave discriminants can play a very important role in the verification process. For this reason, work on their development has formed an important part of Canadian discrimination research.

A recent paper (11) reports progress towards developing an effective P-wave discriminant for United States underground explosions using YKA data. Results from
short-period P-wave discrimination research on Eurasian events were reported independently by Canadian and Swedish seismologists to a conference held at Oslo in November 1971 (12, 13). The similarity in approach of the groups from the two countries in pursuing an effective short-period P-wave criterion led to a co-operative programme to assess the improvements that might be achieved by a multistation approach. The result, that the use of two stations produced a significant improvement over that achieved by either alone, was reported last year in document CCD/380 (8) and in the seismological literature (14). Research is continuing, both separately and co-operatively, on this subject using data from the Yellowknife (YKA) and the Swedish array station at Hagfors (HFS).

The joint research was limited to those events common to both the YKA and HFS data libraries: for the case study reported, 135 Eurasian earthquakes and 30 Eurasian explosions. The two data libraries are now being augmented in parallel to assemble a suite of common events as large as possible and a co-operative research programme is actively continuing. The problems now under study relate to the optimum mathematical formulation of the discriminant calculation using data from the two stations, an improvement in the statistical significance of the results employing broader data bases, an assessment of the required modifications of the criterion for application to a broader range of seismic regions, and a definition of the threshold of application of the method in terms of earthquake magnitude and explosion yield. With respect to the latter, the multinational ISM project will provide the necessary event information to assess the thresholds of application for seismic regions within "third zone" distance to both stations (most of the northern hemisphere and some peripheral regions of the southern hemisphere).

Whereas the mathematical analysis applied to the P-wave data in the initial separate research projects differed in detail, the joint research has led to improvements in technique. Because of the empirical nature of this discriminant, the optimum technique for one station may not be optimum for another and, in fact, may no longer be optimum when data from the two stations are combined. This important practical co-operative research has led to the present YKA short-period P-wave discriminant for Eurasian events: an illustration of the power of the method in a Eurasian case-study is described later.

Although multistation short-period P-wave discrimination has been shown to be a very effective tool, requiring additional research and assessments including more stations, the capabilities of a single station alone can also be very important to the envisaged verification process, since on-line automation and thus event screening appears to be feasible. As described earlier, the CANSAM system will ultimately contain an on-line short-period discrimination processor; how the results of such an on-line scheme may be employed in an operational verification mode is outlined in the final section of the present paper. A comprehensive evaluation of the YKA single-array capability is thus clearly required. The YKA data base for Eurasian events has now been increased to 216 shallow-focus earthquakes and 71 presumed explosions, and provides a valuable background experience against which any current Eurasian event can be judged, in either an operational or a research mode. The multinational project, repeatedly referred to in the present paper, has provided a very large suite of low-magnitude earthquakes for most seismic regions within third zone distance of Yellowknife; these events are, in current research projects, being employed in an expanded assessment of the YKA single-array capability.
A multinational co-operative study of the characteristics of low-magnitude earthquakes - the International Seismic Month Project (ISM)

As described in the United States working paper CCD/388 of 1972, a co-operative multinational project was undertaken, under the aegis of the Lincoln Laboratory of the Massachusetts Institute of Technology, to seek answers to a number of scientific and operational questions related to detection and discrimination using all available seismic data. The most recent progress report on this project is given in the Semi-Annual Technical Summary Report to the Advanced Research Projects Agency of December 1972 of the Lincoln Laboratory (15). The name given to this project is "International Seismic Month", or ISM, an acronym used henceforth in the present paper.

Briefly, ISM is a well-coordinated attempt to define and study global seismicity for a 29-day period (20 February to 19 March 1972) using all available, voluntarily contributed seismic data. Conceptually, the project can be broken down into two parts: (a) the detection and location of seismic events down to the lowest possible magnitudes using all available P-wave recordings, and (b) a multifaceted study of the characteristics of these seismic events and any implications this may have on the scientific and operational aspects of seismological discrimination and test ban verification. Canadian seismologists are involved in both aspects of this project. The seismological data contributions from Canadian stations will be outlined, followed by some preliminary discrimination analyses of events from the ISM bulletin.

The scope and nature of the ISM project is such that analyses of the data may well continue for two or three years, but, to quote from working paper CCD/388, "for the first time we will be in a position to accumulate a single list of events which will form a common and agreed data base for comparative studies". The accumulation of the list of events, or ISM bulletin, is the principal initial project undertaken by the Lincoln Laboratory. At the time of preparation of the present paper, a preliminary bulletin had been distributed to participating agencies and work was nearing completion on a final bulletin, which will contain all events to the practical detection and location limit of the stations employed. Thus, the analyses presented here, on the basis of a preliminary bulletin, cannot yet be finally interpreted in terms of detection/location thresholds or in terms of the total number of events that will in the end be available for the ISM period. However, it will become evident that the lowest magnitudes to which practical discrimination analysis can be applied are already sufficiently complete in the preliminary bulletin for significant conclusions to be drawn.

Canadian P-wave detection for ISM

The Canadian contribution to the detection/location aspect of ISM consisted of P-wave arrival times and P-signal amplitudes of all detectable events from 23 stations of the Canadian Seismograph Network and P-arrival data (time, amplitude, velocity and azimuth) from digital processing of the Yellowknife short-period array records. Comparison with the ISM bulletin events then allows an assessment of each station's contribution to the event detection/location process.
To do this, it is necessary first to establish as accurately as possible the body wave \( m_b \) magnitude for each of the bulletin events against which a particular station's performance can be judged. Thus, all available P-wave amplitude data (from NOAA earthquake data reports, LASA and NORSAR bulletins and the Canadian stations) were combined to compute relatively accurate \( m_b \) magnitudes for events within detection range of the Canadian stations. (Preliminary \( m_b \) values in the ISM bulletin were not based on all available P amplitude data.) Such an assessment of \( m_b \) becomes the scale against which all analyses of detection or discrimination will be defined, both here in these preliminary analyses and eventually for all the final ISM bulletin events.

P-wave detection results have been obtained in the form of the \( m_b \) magnitude at which there is a 90 per cent interval detection probability for all events within the distance range 20° to 90° from each station. The results for the Canadian Seismographic Network stations substantially confirm that the assumptions made in reference (3) were conservative: the more sensitive stations have a better than formerly predicted capability of detecting some of the smaller events and the earlier integrated capability on a northern hemisphere basis should be comfortably achievable by data integration. The Yellowknife array performance during the ISM has also been assessed. In general, the YKA results confirm those presented earlier (3) and published in detail in the scientific literature.

This preliminary ISM analysis suggests that detection with adequate location from a world-wide distribution of medium-aperture arrays should have a 4-station earthquake P-wave detection threshold between \( m_b^{4.0} \) and \( m_b^{4.2} \) in the northern hemisphere (defining this threshold as 90 per cent probability of detection by four or more stations of the network). Thus, so far as detection of P-waves is concerned, it is concluded from the present state of analysis that the conservatively defined northern hemisphere threshold described in reference (3), using data integration from currently operating arrays and the best standard stations, would be improved, that is, lowered, by about 0.3 magnitude units only, if the deployment of upgraded stations, such as suggested in documents CCD/296 and CCD/388, were implemented. Since the present detection capability from P-data integration exceeds the present identification capability using world-wide data, the deployment of additional detection capability needs supplementing by identification capability. Even if P-wave discrimination criteria as good as those developed for the Yellowknife array can be developed for the improved stations, only a small lowering of the identification threshold will follow. At present it is difficult to predict this numerically, but there are sound reasons from YKA experience and published surface-wave studies for assuming that the potential improvement in identification with additional deployment will always be slightly poorer than the improvement in detection. Thus, the differences from additional deployment may reduce to a factor of two only in the yield of the threshold explosion which can be discriminated, a benefit which only a political-military decision can weigh against the cost.

4.2 Canadian Rayleigh-wave detection for ISM

Upon receipt of ISM event bulletins from the Lincoln Laboratory, each participating group has the opportunity to make what contribution it can to an understanding of this series of events: one such project that Canadian seismologists have undertaken is described later in this section. The Lincoln
Laboratory group is also undertaking a compilation of all available Rayleigh-wave information for ISM events whose Rayleigh waves can be detected. This compilation, when complete and analysed to produce $M_s$ magnitudes in addition to $m_b$ magnitudes, will provide an invaluable set of global earthquake $M_s$-$m_b$ data which can be used to assess $M_s$-$m_b$ discrimination characteristics on a much wider scale than formerly possible. As this $M_s$ data analysis is not yet complete, it is only possible to summarize Rayleigh surface-wave data contributions made from the Canadian seismic facilities, although, in addition, Rayleigh-wave data measurements from microfilm recordings from Eurasian stations have been contributed from Canada.

The detailed results will be described elsewhere. Unfortunately, in contrast to the P-wave case, an analysis of Canadian data does not lead easily to any conclusions related to station thresholds of Rayleigh-wave detection for the ISM project. This result was predictable from the results projected in document CCD/327. Virtually all the ISM seismic activity occurred outside Canadian territory; thus, the long and complex propagation paths to Canada from most active seismic regions precludes Canadian stations alone being of value in low-magnitude discrimination studies, the exception to this being the seismic regions of the United States and Mexico from which Rayleigh propagation to Canada is highly efficient.

Once again, the surface-wave detection results indicate the necessity of access to seismic records or information obtained on the same continent as the source event. Since the surface waves are an important part of the verification process, the necessity or otherwise of total or selected long-period data transmission, in real-time or with delays, relates to the operational verification mode politically acceptable in a comprehensive test ban.

The studies of the detection of Rayleigh waves for ISM already completed in Canada can provide further evidence regarding the most valuable types of long-period seismic instruments for discrimination. This problem regarding the optimum seismic instrumentation for discrimination studies is referred to in section III of document CCD/388.

The nine stations in Canada, selected for Rayleigh-wave measurements, include among them four different types of long-period vertical seismographs. A comparison of the Rayleigh-wave detection on these four different instruments provides useful comparative information. In general, the conclusions reached are in agreement with the United States conclusion that the optimum LP instrument is one with broad-band response, say 10- to 100-second periods, but with effective microseismic noise rejection. Additional improvements achieved by strict environmental control, for example, by deployment in boreholes, would be a bonus. Digital recording would provide the greatest dynamic range and facilitate signal analysis.

4.3 An ISM-Eurasian case study using joint $M_s$-$m_b$/P-wave/focal depth discrimination

The ISM project for the assessment of low-level global seismicity has provided the necessary background data for numerous studies of seismic discrimination. These studies may continue for some time in order to achieve a good understanding of the many outstanding problems. However, in view of the assessment made in 1971 in document CCD/327 that discrimination of Eurasian events at that time was limited by the poor detection and location capability of low-magnitude earthquakes, the
first detailed Canadian study of the events provided by this co-operative project has concentrated on an interim determination of the capability to identify Eurasian earthquakes as such, using the joint application of focal depth, P-wave characteristics and $M_s$:$m_b$ criteria. This is, therefore, in concept, an attempt to understand more completely the natural seismic background against which possible explosions must be judged in an operating seismic verification process.

The analysis and adjustment of P-wave ($m_b$) magnitudes for the ISM events has made available a suite of 265 Eurasian earthquakes reasonably well fixed in apparent size within the $m_b$ magnitude range, which is the magnitude scale related to detection and location capabilities and thus to thresholds of available event information. It should be noted that there is a residual of detected and located events within this time period for which accurate $m_b$ magnitudes cannot yet be independently assigned from the available data. The 265 events to be described are illustrated in four regional Eurasian blocks in figure 1: for purposes of discussion, the regions are called Middle East, Central Asia, Japan-Taiwan and Kamchatka-Kurils. The background information on this map shows seven years of Eurasian seismicity. The 265 events to be described, although providing a good sampling of this seismicity, are not plotted as individual epicentres; the figure is used simply to illustrate the number of events within each region.

The analysis applied can be described with respect to the station information shown in figure 1. The Yellowknife array short-period P-wave discriminant was applied to each of the event P-waves with sufficient signal-to-noise level as recorded at Yellowknife. The nine Canadian long-period seismic stations noted in the legend to the figure and the 10 Eurasian long-period seismic stations plotted on the map were employed to define preliminary $M_s$ magnitudes for all events with detectable Rayleigh waves on one or more stations. With all $M_s$ magnitudes adjusted where necessary to avoid as much as possible the regional biases described in document CCD/327, the two magnitudes together provide the $M_s$:$m_b$ discrimination data.

With the stated intention of attempting to identify these events as earthquakes to the lowest possible levels, the results for each event were judged against experience for each criterion accumulated for Eurasian earthquakes and explosions over some years. This "data base" experience is represented by the large populations of Eurasian events described earlier in the present paper for which the Yellowknife discrimination parameters are available, and the $M_s$:$m_b$ data bases for Eurasia accumulated in 1971 and described previously in document CCD/327 (4, see also 16). For each criterion separately, the data base populations were employed to define multiparameter discrimination functions which optimize in a statistical way the separation between the explosion and earthquake populations. Each pair of discrimination functions is then employed to define an earthquake index function ($QX$) which relates to the probability that a given event belongs to the earthquake population. $QX$ is computed on a scale from 0 to 100, with 0 indicating an explosion-like event and 100 indicating an earthquake-like event. Thus, a complete discrimination analysis for an event is reduced to two earthquake index numbers if both criteria can be applied, or to one number or no result if only one or neither criterion can be applied. This procedure was applied systematically to the 265 Eurasian events.

The fundamental information available for each event is its computed epicentre and computed (or assumed) focal depth. It is apparent from figure 1
Figure 1

Background map of Eurasia shows epicentres for seven years of seismicity.

Number in box associated with each of the four circular regions is the number of seismic events located within the region that were studied in the discrimination analysis of the International Seismic Month (20 February to 19 March 1972). Canadian stations employed in discrimination analysis are indicated in legend; Eurasian long-period stations employed for Rayleigh-wave measurements are plotted on map.
that earthquakes are included in the data set from unlikely explosion locations. These and other regions, for example, Kamchatka, are locations for which no experience of explosion characteristics is available. This, of course, was intentional, since one purpose of the study was to provide as complete as possible a picture of the highly variable earthquake characteristics.

The available information on focal depths for these events is an important piece of event information. In the routine computation of earthquake locations, if sufficient P travel-time observations are available, the computations can fix the earthquake in three dimensions, that is, its epicentre co-ordinates and focal depth. If, however, the available observations are insufficient, the earthquake is restricted at an assumed depth and the computation proceeds to determine the epicentre co-ordinates only. It is generally agreed that depths about 60 kilometres and greater are sufficiently accurately determined routinely to provide positive earthquake identification. Thus, all ISM events with computed depths greater than about 60 kilometres can be removed as potential problems, leaving the shallower and the restricted depth events.

The logic followed in the event analysis is illustrated in the following table. Let \( QX_1 > 90 \) represent the decision that an event is an earthquake using the \( M_n \) criterion, and \( QX_2 > 90 \) the decision that an event is an earthquake using the P-wave criterion. The screening/decision procedure is then as follows:

<table>
<thead>
<tr>
<th>Screening level</th>
<th>Criteria available</th>
<th>Test applied</th>
<th>Decision</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 and 2</td>
<td>( QX_1 &gt; 90 ) and ( QX_2 &gt; 90 )</td>
<td>earthquake</td>
<td>39</td>
</tr>
<tr>
<td>2</td>
<td>1 and 2</td>
<td>( QX_1 &lt; 10 ) and ( QX_2 &lt; 10 )</td>
<td>explosion</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1 and 2</td>
<td>( QX_1 &gt; 90 ) and ( QX_2 &gt; 70 ) or ( QX_2 &gt; 90 ) and ( QX_1 &gt; 70 )</td>
<td>earthquake</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>(focal depth &gt; 60 km)</td>
<td></td>
<td>earthquake</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>1 or 2</td>
<td>( QX_1 &gt; 90 ) or ( QX_2 &gt; 90 )</td>
<td>earthquake</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>(treated but none of above)</td>
<td></td>
<td>?</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>(not treated)</td>
<td></td>
<td>?</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>265</td>
</tr>
</tbody>
</table>

Some variation in the procedure followed can easily be tolerated, but the immediate result of the above sample procedure is that 12 of 265 events (those arising from screening level 6) remain for detailed consideration as potential problems. In the above table, the explosion decision on an \( m_{5.5} \) event in Eastern Kazakh is made at a high screening level. In an operational application of such a screening procedure for comprehensive test ban verification, this event would be retained for further consideration with the 12 events from level 6. The level at which the focal depth criterion is placed is also subject to consideration: here at level 4 it is screening a number of low-magnitude earthquakes for which neither of the discrimination criteria is available.
Further consideration of the potential problem events

The 12 events which, from the screening procedure, might be interpreted as potential problems, are listed in the following table. These will be considered further in detail.

<table>
<thead>
<tr>
<th>No.</th>
<th>Date  (1972)</th>
<th>Time (GMT)</th>
<th>mb</th>
<th>Region</th>
<th>QX1 (Mg:m_b)</th>
<th>QX2 (P Wave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 Feb</td>
<td>03 02 14</td>
<td>4.9</td>
<td>Tibet</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>23 Feb</td>
<td>14 00 49</td>
<td>4.4</td>
<td>Hindu Kush</td>
<td>--</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>28 Feb</td>
<td>16 24 08</td>
<td>3.9</td>
<td>North of Persian Gulf</td>
<td>89</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>28 Feb</td>
<td>16 26 57</td>
<td>4.0</td>
<td>&quot;</td>
<td>84</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>28 Feb</td>
<td>17 22 55</td>
<td>4.5</td>
<td>&quot;</td>
<td>4</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>29 Feb</td>
<td>11 22 49</td>
<td>4.3</td>
<td>&quot;</td>
<td>--</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>29 Feb</td>
<td>23 42 40</td>
<td>4.4</td>
<td>Kamchatka</td>
<td>--</td>
<td>79</td>
</tr>
<tr>
<td>8</td>
<td>02 Mar</td>
<td>14 10 13</td>
<td>4.3</td>
<td>North of Persian Gulf</td>
<td>--</td>
<td>65</td>
</tr>
<tr>
<td>9</td>
<td>03 Mar</td>
<td>00 39 23</td>
<td>4.3</td>
<td>Kamchatka</td>
<td>--</td>
<td>04</td>
</tr>
<tr>
<td>10</td>
<td>08 Mar</td>
<td>02 38 11</td>
<td>4.4</td>
<td>Sea of Okhotsk</td>
<td>--</td>
<td>00</td>
</tr>
<tr>
<td>11</td>
<td>12 Mar</td>
<td>17 31 12</td>
<td>4.6</td>
<td>North of Persian Gulf</td>
<td>54</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>16 Mar</td>
<td>17 30 27</td>
<td>4.1</td>
<td>Sakhalin Island</td>
<td>100</td>
<td>00</td>
</tr>
</tbody>
</table>

Note first that most of these events are in the magnitude range below m_b<4.5, the magnitude that will later be shown to be the 90 per cent interval application threshold of the process.

Event 1 from the Tibet region is an example of difficulty in m_s:m_b discrimination in this region illustrated in section II of document CCD/388. As shown in the table, it is earthquake-like by the P-wave criterion and can be eliminated in this way.

Events 3, 4, 5, 6, 8 and 11 are from earthquake swarms north of the Persian Gulf. At the lower magnitudes for these events, the M_s values in this preliminary analysis are defined from a single regional station (EIL in figure 1). The M_s:m_b characteristics of some of these smaller events are trending towards an extrapolated portion of the Eurasian explosion M_s:m_b trend. Thus, the basic difficulty may be a lack of knowledge of explosion characteristics in the range m_b<3.9-4.5 (there are none in this range in the Eurasian data base population; see document CCD/327), with the further possibility that a single regional M_s determination may be biased. Note that, for events 6 and 11, as the magnitudes rise above the P-wave criterion threshold, they are earthquake-like by this criterion.

Events 2, 9 and 10 are below the M_s:m_b threshold capability and are explosion-like by the P-wave criterion. Each of these events was assigned a restricted (N) depth in the hypocentral computation, but each is from a seismic
region with numerous deep earthquakes. A further processing of the YKA data reveals the P phases of these events to be very explosion-like (as are the P phases of large, deep events from the same regions), but the beam trace of each contains, in addition, one stable signal arrival (at the appropriate azimuth and slowness) within two minutes of the P-wave onset. If these secondary signals are interpreted as surface reflections (pP), then the Hindu Kush event has a depth of about 130 kilometres, the Sea of Okhotsk event a depth of about 700 kilometres, and the Kamchatka event a depth of about 50 kilometres. Observation of pP at one station is not sufficiently unambiguous to place an earthquake at great depth (the signals could, for example, represent P waves from a double shock from the same region), but this clearly demonstrates the value of short-period array processing in searching for such depth phases, and underlines the necessity for doing the processing routinely for more events at more array stations.

Event 12 is a presumed earthquake on the northern end of Sakhalin Island, which on the seismicity maps is a region of shallow, but infrequent, seismic activity. This event is explosion-like by the P-wave criterion and earthquake-like by the $M_S$ criterion, with the $M_S$ based on a single Rayleigh wave observation (CHG in figure 1). This event is only marginally above the application threshold of each criterion employed separately, so that for certain identification, further information is required.

Event 7 can only be tested by the P-wave discrimination process with the data currently available: it was formally found to be slightly less earthquake-like than the rigorous tests adopted in the screening process to specify an earthquake. It is, however, judged to be an earthquake, but further study would be desirable in an operational verification mode.

4.5 Implications of ISM-Eurasian study

Figure 2 shows histograms as a function of body-wave magnitude $m_b$ of the treated and untreated events that result from the screening procedure described above. Between the two histograms is shown an application probability curve. This is computed as the percentage of treated events from the total events in each 0.1 $m_b$ interval. It is clear that there are sufficient events in the total population to define this curve accurately; there is a 90 per cent interval probability of applying this type of discrimination analysis at $m_b$. Can this be interpreted in terms of a discrimination threshold? To answer this question, it is essential to reconsider what was done in this experiment. The background seismological experience included many things: the capabilities of the discriminants employed, including their thresholds, the seismicity patterns in Eurasia and the tectonic fabric of the region, the locations, rate of occurrence and magnitudes of previous explosions etc. Given this experience, a suite of 265 new seismic events was analysed with the specific intention of defining the number and location of events that appear explosion-like. The results, to the limits of the capability of the procedures employed, have been stated earlier. The application probability curve in figure 2 summarizes this capability.

There was one explosion ($m_b 5.5$) in this population; its magnitude, location and the results of the two discrimination criteria have clearly identified it as such. What would the results have been if there had been, say, five explosions in this suite of events in scattered locations and ranging in magnitude from
Application probability curve is computed as the percentage of treated to total events within each 0.1m_b interval. Application probability is 90 per cent at m_b 4.5, 50 per cent at m_b 4.2
m_{4.0} to m_{5.0}? This is very difficult to answer, and the answer essentially prejudges the result of the techniques employed as if they were being employed in an operational verification scheme. Nevertheless, there is a high probability that explosions with body-wave magnitudes greater than m_{4.5} would have been defined as such in the simulated operational procedure. This corresponds to yields between 5 and 10 kilotons in hard rock with no evasion tactics. There is, furthermore, an appreciable probability of identifying explosions of m_{4.2}, or, say 2 to 6 kilotons in hard rock with no evasion tactics. The levels of confidence used are thought to be conservative.

There is good evidence from this preliminary ISM analysis that the data from current systems when integrated has a 90 per cent interval probability of detecting and locating Eurasian events at about m_{4.2}. This more than doubles the total number of events that otherwise would have been available from this region. Any effective operational discrimination analysis of low-magnitude events in numbers that will be produced by such co-operative schemes must have an effective screening procedure for events that require little or no further consideration: one very efficient screening parameter is focal depth and it is in this aspect of discrimination that further research may make the greatest contribution.

The sample screening/decision procedure employed here has an application threshold at m_{4.5} (90 per cent interval). It remains for further extensive analysis using large-aperture arrays and digital processing of VLP station records to establish whether this conservative application threshold can be reduced nearer to the detection threshold. Reasons have been given previously (4, 5) to indicate that a 4-kiloton hard rock yield target should be attainable with further technological deployment and that, near the limit, this might reach 2-kiloton hard-rock yield. (The yield figures quoted assume no evasion tactics.) These modest extrapolations may represent the present technological limit and the cost of obtaining additional improvement, such as a factor of two, over the present intrinsic capabilities may be high. Policy judgements, as in the past, will govern this cost-benefit calculation.

It must be noted that only two of the 12 treated events which failed the passes through the screening process have magnitudes m_{4.5} exceeding 4.5. For these events, as described earlier, there seems no doubt from analyst study that they are earthquakes. Of the remaining potential problems, all should ideally be subjected to more data acquisition and study, but current analyst judgement suggests that they are earthquakes. Finally, it should be noted that these 10 potential problem events are all below the 90 per cent application threshold: expressed another way, it can be asked whether excessive attention to these 10 events would be justified when 119 detected and located events cannot be treated at all with the data currently analysed.

5. Deterrence and false alarms - The uncertainties in the decision-making process in seismic verification

5.1 The interpretation and extrapolation of seismic discriminants

There have been serious differences of opinion on the need for, number and, indeed, effectiveness of on-site inspections of contested events, the effectiveness of procedures to refute a challenge, the meaning of adequate deterrence and other areas where policy judgements interact clearly with the technological capabilities.
Although no general rules can be formulated, it should be realized that many such arguments in this area depend critically upon the power of the seismic discriminants used and the technological equivalent yield limit implicit in their use. It is believed that this limit has been roughly defined in the case of seismological method. It enters in two ways: firstly, in the assessment of the power of the seismological detection and discrimination process and, secondly, in the increasing number of background natural events or earthquakes which an operational verification scheme must screen. As the power of seismological methods improves into lower and lower equivalent yield explosions, the number of earthquakes which potentially require consideration rapidly escalates.

One technical approach has been outlined in the Swedish working paper CCD/329 42/ of 1971 (17) which, with its accompanying publications, introduced an extensive analysis of such concepts, including also such non-scientific factors as required deterrence for a would-be violator and the politically tolerable false alarm rate in the situations of a test ban, with and without on-site inspection. Much progress has been made since that time: estimates of regional seismicity have been improved as discussed elsewhere, regionally perfect M :m, discrimination has been reported and short-period discriminants are being perfected. However, the problem of the confidence to be placed in extrapolation of existing discriminants to the extreme levels of probabilities, which are deemed necessary by some studies in the design of a realistic test ban, has not received its due attention.

This is a question to which Canadian scientists have been turning their attention. Firstly, the concept that the "false alarm probability" is a trade-off against "adequate deterrence" appears generally acceptable. However, technical uncertainties and possible disagreements remain for scientific resolution. Two areas of concern can be identified. The first is whether the behaviour of known discriminants based on past underground explosions can be extrapolated to future underground explosions. In particular, the data base for underground explosions is not too extensive and there is the possibility that explosions conducted under evasion scenarios, even when these explosions are seismically detected, may not follow the currently known discriminant patterns. Some suggestion of variable discrimination patterns is seen in the deeper Ural explosion M :m, divergencies from eastern Kazakh explosion behaviour (4, 16). The second is whether statistical assumptions usually made to extrapolate limited experience are safe for this problem. This is a technically complex area where there is room for further research and technical exploration. For example, in much recently published work, normal distributions of the parent populations are assumed: a population average and its probable error are quite robustly determined under this assumption, but the variance or scatter of the parent population is much less reliably predicted. Another example is the short-period P-wave multivariate discriminant function described earlier. The method used to define the function is derived under several assumptions about the underlying distribution function, that is, that all variates are normal and their dispersion identical. Only in this way can the heavy algebra be handled. The optimum criterion is then stated as the

42/ Ibid., Supplement for 1971, document DC/234, annex C.
minimum total cost of errors: this involves an integration of "error cost" times "error probability" over the tail ends of the distributions. These tails are arbitrarily defined, but may not be observed.

It is concluded from studies by Canadian scientists (18) that, when the "adequate deterrence" is lowered sufficiently to reduce the false alarm probability to a fraction of 1 per cent, a prudent approach may be to avoid possibly extravagant extrapolation and to make claims only by conservative means using actually observed sample populations and stating confidence limits derived from distribution-free methods.

5.2 Discrimination results from a global suite of $M_s$ : $m_b$ data

These suggestions and their consequences can be illustrated using the bivariate $M_s$ : $m_b$ discriminant for a global earthquake and explosion sample population. The different data sets making up the global population are described in a recent publication (18), together with a detailed justification of magnitude adjustments made in order to normalize the sets to the same basis.

The total suites of $M_s$ : $m_b$ data (99 explosions and 613 earthquakes) are shown plotted in figure 3. Figure 4 shows the cumulative discriminant functions distribution for the explosion and earthquake populations. It is in the interpretation of such plots as these that differences of opinion arise; in particular, how they should be extrapolated beyond the observed range and what confidence limits can be placed on the extrapolation. Briefly, it is considered that a conservative approach requires that the actually observed discriminant not be extrapolated far beyond the observed populations, and that the uncertainty in the tails of the distribution where the argument lies be derived without assuming an arbitrary distribution. In practice, this means for these curves that if, for example, a policy judgement requires at least 20 per cent deterrence, a 30 per cent deterrence might better be adopted in order to achieve 20 per cent deterrence with 95 per cent confidence and, in this case, the false alarm probability is empirically near 0.1 per cent, with 95 per cent confidence that it is less than 5 per cent. Since this data set for this discriminant appears to be the most extensive published in the open literature, it is clear that technical uncertainties as to the confidence in the results and thus in the number of expected false alarms in a given region still remain to be resolved. Mathematical considerations of the "distribution-free" method indicate that progress along these lines will be slow.

5.3 Test ban decision-making

In an earlier section, the Eurasian ISM data were analysed by a step-by-step process. It is necessary to ensure that assumptions are not built into this process which may prove untenable under conservative analysis. The procedure used there to make an earthquake or explosion decision was based initially on a formally calculated index of earthquake-likeness. The use of the word "probability" instead of "index" was carefully avoided, even though under strictly normal behaviour of all variates this would have been appropriate. All events which are not reasonably close to 0 or 100 per cent earthquake-likeness were then subjected to a hierarchical procedure of successive discriminants and analyst judgement. The first step in this procedure effectively reserves a decision near or in the region of overlap of the two event types. This is equivalent to a distribution-free discrimination scheme now under active consideration. Here an
Explosions are denoted as circles and earthquakes as stars. The explosion trend line is employed as the base line for the discriminant function.
Figure 4

Cumulative distributions of earthquake and explosion discriminant functions measured relative to the explosion trend line in figure 3

For a given value of the discriminant function, the percentage associated with the explosion distribution represents expected deterrence (correct explosion identification probability) and the percentage associated with the earthquake distribution represents expected false alarm probability. Confidence curves at the 95 per cent level are shown for the minimum value of deterrence and maximum value of false alarm probability. The results for the 30 per cent deterrence requirement described in the text are illustrated on the figure.
event is classified by comparing its variates with the variates of the sample
group in descending order of discrimination power. If the event variate value
falls in the region of overlap of earthquakes and explosions, no decision is made
and the next variate is selected. Only if no decision can be reached after passing
through all variates is the event classified as a problem event deserving further
study. Thus, in an earlier section of the present paper, further study involved
more array processing and searching for depth phases, that is, an attempt to
improve the focal depth variate.

This concept is quite different from one that would simply employ an
accumulated earthquake and explosion $M_S:mb$ data base to make a decision concerning
a single event or a group of additional events of interest. For example, the
false alarm probability defined in figure 4 for the global $M_S:mb$ data base gives
the average probability of making an explosion decision in error from the one
discriminant. In the proposed multivariate screening procedure in which the
$M_S:mb$ result is one of the variates, no decision would be made unless the result,
say the $M_S:mb$ earthquake index of subsection 4.3 or the discriminant function of
figure 4 (these are related but not mathematically identical), indicates the event
is far from the region of overlap of the two populations. An event which does not
fall into this category is transferred to the next variate and so on until all
analytical procedures have been exhausted. If applied to a large group of events,
this procedure would likely leave a residual number of suspicious or problem
events above the particular application threshold that pertains to the procedure.

In a practical seismic verification mode for a comprehensive test ban, each
step in the event classification would be restricted to an "earthquake" decision,
with possible explosions transferred through the screening level until they emerge
as part of the residual problem events. The "explosion" decision is made at this
final level, that is, that the residual events are presumed to be explosions. Any
explosion-like earthquakes that remain in this group are, of course, real false
alarms as distinct from probabilistic false alarms arising from consideration of
single discriminants. The deterrence achieved by these schemes can be very high,
but it is completely adjustable over a wide range by the trade-off which must be
made by the policy-maker between what he considers as "adequate" deterrence and
"acceptable" false alarm probability. The adjustment is simply made at the
decision level of each variate in the above screening procedure.

Tests of this procedure that may assist the policy-maker in finding the
appropriate trade-off position mentioned above are being actively pursued in
Canada. The only results available to date, and these are preliminary, are those
described for the ISM Eurasian events in subsections 4.3 to 4.5 above. As a
simulated verification scheme, the result was one explosion decision and no false
alarms above the application threshold of $mb^{4.5}$, with very high implicit
deterrence above five kilotons in hard rock assuming no evasion tactics.

5.4 A possible international seismic discrimination network

The degree of sophistication and the levels of confidence the procedures
require as the event identification process is systematically implemented are
matters that require operational decisions from both the political and
seismological sides of the verification issue. The former guidance will not be
obtained until there is political agreement. However, since the seismic
discrimination process is perhaps less contentious, a Canadian view of an
international discrimination network consistent with the approach in the present
paper is next described.

-143-
In an operational, monitoring mode there appear to be two general competing approaches. The first follows the research network outlined in document CCD/388 with its emphasis on the real-time detection of seismic events and mass storage and transmission of seismic data using international and national communications networks. The sequence of actions required to make decisions on difficult events is not explicitly described. Thus, although detection and location may be possible in real-time, the time required to make decisions on difficult events is undefined and would be substantially delayed from real-time.

An alternative concept consists of a number of national facilities meeting minimum data compatibility standards: the Yellowknife medium aperture short- and long-period array and the CANSAM system might be a typical such facility. The daily detection logs can then be cheaply transmitted each day to a central analysis facility, such as the existing SAAC in the United States of America, and a detection and location log compiled no later than 1 to 2 days in arrears. Abstracted data on events of interest to national centres are then retransmitted to the co-operating centres.

Meanwhile, national centres might establish, by automated P-wave discrimination or conservative Ms:mb procedures, screening procedures to reduce appreciably the number of events for further analyst consideration. At the present time, the step-by-step approach described above appears to be the optimum. In a time frame typically delayed 7 to 20 days from an event of interest, digital tapes or analogue records of the residual events of interest should be obtainable by any one centre from any other national centre by air express, or by a dialled, but not dedicated, communication link or some other reliable means. National centres could establish their own schedules for final decision-making, but this should be possible within event-time plus (say) 30 days.

Beyond this outline of a possible network, it does not seem worth while to continue speculation, since the next stages in such an operational network procedure involve the political form of a comprehensive test ban - the possibility or otherwise of on-site inspection, the mechanisms which might be used to make and refute a challenge and/or other concepts. So far as can be judged, a group of co-operating national centres would supply at minimum cost the optimum operational discrimination network, leaving flexibility to each centre to make national judgements and to decide what events from what area are its primary national security concern and thus where its dominant effort will be placed. Provided some agreed time-tables for abstracted and limited full data exchange are met, guarantees given of continuing operation, and provided data formats have a minimum compatibility, such a system would give freedom to a number of countries to make a useful contribution. This concept would allow a more technologically developed country with a particular interest in the seismic data which could be acquired from the territory of a smaller country to provide bilateral assistance in station development. This capability for contribution by several countries could provide increased deterrence against attempted clandestine violations of a comprehensive test ban. The political options open to any nation in the event it was convinced of a violation would not be affected, except in so far as an agreed time, such as the 30 days suggested above, would be necessary to implement seismic decision-making.

The elements of such a network already exist and expansion plans which would usefully contribute have been described in document CCD/388. A truly flexible operational verification system might be evolved from the national components.
allowing each contributing country to decide on its national objectives within an agreed minimum set of rules for data compatibility, time-tables for exchange and guarantees of operating lifetime.

6. Conclusions

(a) The concept of a practical technological limit to the teleseismic discrimination of underground nuclear explosions has been made more precise. In one extensive study, which has not yet exhausted all the internationally available data, it was proved that there is a 90 per cent chance of applying seismic discrimination techniques to events as low as body-wave magnitude $m_b 4.5$. This is equivalent to defining conservatively an effective Eurasian threshold between 5- and 10-kiloton yield in hard rock with no evasive tactics.

(b) Calculations, verified from detailed comparison with data acquired during the multinational seismic experiment of four weeks' duration, suggest that a conservatively defined teleseismic technological limit for the positive identification of hard rock explosions with no evasive tactics is about 2 to 4 kilotons: below this, the teleseismic method is, in general, of limited promise. If evasion techniques effectively reduce the seismic yield of larger explosions below this limit, the purely teleseismic method is powerless.

(c) With a clear understanding and acknowledgement of this limit, alternative operational verification schemes need practical consideration and policy studies are required of what such procedures as on-site inspection would achieve, or what options exist that would be effective to refute a challenge.

(d) Ignoring evasion possibilities, the misidentification rate of earthquakes as explosions or so-called false alarms using purely seismological methods depends upon the operational methods adopted, the discrimination limit of the deployed network, and a policy decision about what constitutes adequate deterrence.

(e) The provision of seismic data from all Eurasian States would enable progress to be made in the residual false alarm problem. The results of experience with comprehensive data sets may prove more reliable than theoretical calculations of false alarms. In the latter, substantial differences of opinion can arise depending upon the confidence ascribed to how well the available data represent the extreme characteristics of earthquakes and underground explosions.

(f) Currently, a multistep discriminant approach to an operational verification scheme involving multinational co-operation between advanced national facilities appears to provide an attractive way to monitor underground nuclear explosions, and could be developed for the purposes of a comprehensive test ban.

(g) As the seismological limits are reached, more emphasis will be necessary on cost-effective seismic array monitors using small-scale digital processors and on devising optimum operational methods of verification.

(h) The provision of complete technical information on any underground explosions in Eurasia during the interval of the International Seismic Month would provide an unbiased test of the effectiveness of the teleseismic discrimination process and reduce the area of disagreement.
APPENDIX

References


The working paper presented by Japan (CCD/399) commented upon a prior working paper presented by the United States (CCD/388). Following are further comments on three points raised in the Japanese paper:

First, document CCD/399 points out that values of body-wave magnitude determined from few stations, or from stations at relatively small epicentral distances, are of doubtful reliability for the purpose of classifying events by $M_g:m_b$. In particular, event No. 12 of the list (table 4) included in the United States paper had an $m_b$ value which was based on data from a single, nearby station. We agree with the Japanese conclusion that the data presented on event No. 12 are of poor reliability and, therefore, are not sufficient to establish this as an example of an "anomalous" event. We further agree with the general point that data from several stations should be used whenever possible, and the following discussion concentrates only on those earthquakes accepted in the Japanese analysis.

Second, document CCD/399 provides further evidence that $m_b$ is dependent upon the specific reporting stations used and upon the methods used at the centre where the data are interpreted. In particular, the paper notes that, if earthquake $m_b$ reported by the Bulletin of the International Seismological Centre (ISC) is used in place of $m_b$ reported by the National Ocean Survey (NOS), as was done in document CCD/388, the $m_b$ values will generally be reduced. The effect of this reduction in $m_b$ is to remove all earthquakes from the "explosion like" region of figure 5 of CCD/388. It should be noted, however, that the problem of "anomalous" events would still not be solved by such a shift in $m_b$ values, since events remain in the "intermediate region" which may still be statistically indistinguishable from explosions (see CCD/388, p. 16).

Our third and chief comment is that document CCD/399 used ISC $m_b$ values for earthquakes, but interprets them relative to explosions based on NOS $m_b$ values. Since the same factors which affect estimates of earthquake magnitudes also affect explosion magnitudes, it follows that, if earthquake $m_b$ values are to be based on ISC determinations, then explosion $m_b$ values must also be determined in the same way. The figure below shows the $M_s:m_b$ plot for explosions and earthquakes using ISC $m_b$ values for both, as well as consistently determined $M_s$ values. This figure confirms the statements previously given in document CCD/388: earthquakes do occur which are statistically indistinguishable from explosions on the basis of $M_s:m_b$, and actual overlap is observed. Using magnitudes determined in this way, the upper limit for explosions might be represented by $M_s = m_b - 1.2$, rather than

---

\[43/\] Ibid., Supplement for 1972, document DC/235, annex B.
\[ M_s = m_b - 1.5 \] as used in figure 5 of document CCD/388. Data on the explosions are given in the table below.

Possible causes of events with low \( M_s : m_b \) ratios and approaches to improving our understanding of the problem are discussed in some detail in United States working paper CCD/404 above.
$m_b$ was determined by ISC. $M_s$ was determined by Marshall and Basham for explosions, and by a consistent method for earthquakes, as reported in document CCD/388. The line $M_s = m_b - 1.5$ is shown only for ease of comparison with figure 5 of document CCD/388. Explosions included in this study lie below the line $M_s = m_b - 1.2$. 

-150-
Table

Data on Asian explosions used by Marshall and Basham

<table>
<thead>
<tr>
<th>DATE</th>
<th>LOCATION</th>
<th>MAGNITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lat.</td>
<td>Long.</td>
</tr>
<tr>
<td>7 Jan. 68</td>
<td>49.8N</td>
<td>78.0E</td>
</tr>
<tr>
<td>24 Apr. 68</td>
<td>49.8N</td>
<td>78.1E</td>
</tr>
<tr>
<td>11 June 68</td>
<td>49.8N</td>
<td>78.2E</td>
</tr>
<tr>
<td>19 June 68</td>
<td>50.0N</td>
<td>79.1E</td>
</tr>
<tr>
<td>1 July 68</td>
<td>47.9N</td>
<td>78.1E</td>
</tr>
<tr>
<td>12 July 68</td>
<td>49.7N</td>
<td>78.1E</td>
</tr>
<tr>
<td>5 Sept. 68</td>
<td>49.8N</td>
<td>78.1E</td>
</tr>
<tr>
<td>29 Sept. 68</td>
<td>49.8N</td>
<td>78.2E</td>
</tr>
<tr>
<td>7 Nov. 68</td>
<td>73.4N</td>
<td>54.9E</td>
</tr>
<tr>
<td>18 Dec. 68</td>
<td>49.7N</td>
<td>78.1E</td>
</tr>
<tr>
<td>7 Mar. 69</td>
<td>49.8N</td>
<td>78.1E</td>
</tr>
<tr>
<td>16 May 69</td>
<td>49.7N</td>
<td>78.1E</td>
</tr>
<tr>
<td>31 May 69</td>
<td>49.9N</td>
<td>77.7E</td>
</tr>
<tr>
<td>4 July 69</td>
<td>49.7N</td>
<td>78.1E</td>
</tr>
<tr>
<td>23 July 69</td>
<td>49.8N</td>
<td>78.3E</td>
</tr>
<tr>
<td>2 Sept. 69</td>
<td>57.4N</td>
<td>54.8E</td>
</tr>
<tr>
<td>8 Sept. 69</td>
<td>57.3N</td>
<td>55.1E</td>
</tr>
<tr>
<td>22 Sept. 69</td>
<td>41.3N</td>
<td>88.2E</td>
</tr>
<tr>
<td>26 Sept. 69</td>
<td>45.8N</td>
<td>42.4E</td>
</tr>
<tr>
<td>1 Oct. 69</td>
<td>49.8N</td>
<td>78.2E</td>
</tr>
<tr>
<td>14 Oct. 69</td>
<td>73.4N</td>
<td>54.8E</td>
</tr>
<tr>
<td>30 Nov. 69</td>
<td>49.9N</td>
<td>79.0E</td>
</tr>
<tr>
<td>6 Dec. 69</td>
<td>43.8N</td>
<td>54.7E</td>
</tr>
<tr>
<td>28 Dec. 69</td>
<td>50.0N</td>
<td>77.8E</td>
</tr>
<tr>
<td>29 Jan. 70</td>
<td>49.8N</td>
<td>78.2E</td>
</tr>
<tr>
<td>28 June 70</td>
<td>49.8N</td>
<td>78.2E</td>
</tr>
</tbody>
</table>
16. JAPAN

Working paper on a comparison between earthquakes and underground explosions observed at the Matsushiro Seismological Observatory (CCD/408)

Original: English
10 July 1973

1. Introduction

The Matsushiro Seismological Observatory of the Japan Meteorological Agency has recorded seismic waves from many underground explosions. In the present paper, some preliminary investigation is reported on the nature of seismic waves from underground explosions and earthquakes. The seismograms used are SPs and LPs of the World-wide Standard Seismological Network (WWSS).

2. Data

The explosions and earthquakes investigated in the present paper are listed in table 1 below. Origin time, epicentre, focal depth and magnitude are taken from PDE (Preliminary Determination of Epicentres by NOAA). The values of mb and Ms at Matsushiro are determined according to the following formulae:

\[ mb = \log \left( \frac{A}{T} \right) + Q, \]

where A and T are the maximum amplitude and the corresponding period.

\[ Ms = \log \left( \frac{A}{20} \right) + 1.66 \log \Delta + 3.3, \]

where A is the horizontal amplitude of Rayleigh wave of 17 - 23 seconds in period, and \( \Delta \) is the epicentral distance in degrees. The above two formulae are the same as used in NOAA and no station correction is made for mb and Ms values at MAT.

3. Detection capability

The detection capability of MAT using SP of WWSSN is mb : 5.0 with a probability of 80 per cent for earthquakes in Eurasia and also in western America.

Figure 1 shows the detected and undetected number of the presumed and announced underground explosions in the Nevada Test Site (NTS), Kazakh and Novaya Zemlya. For underground explosions investigated here, the detection capability is nearly the same as for natural earthquakes.

The epicentral distances are about 45 degrees from MAT to the Kazakh region and about 80 degrees, which is almost twice as much, to NTS. It is interesting that the detection capabilities for the two regions are almost the same regardless of the difference in epicentral distance.

-152-
4. \textit{mb}

To calculate \textit{mb} values, the maximum trace amplitude, \textit{A}, and the corresponding period, \textit{T}, must be measured on SP seismograms. However, if a narrow-band seismograph is used as in the present practice, the following problems seem to arise:

(1) Period

The period, which corresponds to the maximum trace amplitude, depends on (a) magnitude of an event, (b) earthquakes or explosions and (c) region of an event.

Figure 2 shows a relation between \textit{T} and \textit{mb} of earthquakes and explosions in central Eurasia and western America. In Eurasian earthquakes, \textit{T} becomes longer significantly with the increasing magnitude. Whereas no such relation is seen for explosions, and \textit{T}s are less than 1 second with a small scatter regardless of the size of explosions. In western American events, these relations are not so clear as in Eurasian events partly due to a smaller amount of data.

Figure 3 shows the frequency distribution of \textit{T} for earthquakes and explosions in both regions. \textit{T} peaks out at about 0.6 second for explosions in Kazakh and 1.0 second for explosions in NTS. On the other hand, for earthquakes in both regions, \textit{T} shows a broader distribution in a longer-period range. It is probably because of the difference in epicentral distance that the \textit{T} distribution is in a range of longer period both for explosions and earthquakes in NTS than in Kazakh.

(2) Deviation of \textit{mb} versus \textit{T}

The relation between \textit{T} and deviations of \textit{mb}, namely, \textit{mb} (MAT) - \textit{mb} (NOAA) is shown in figure 4. For explosions in both regions, deviations are mostly minus when \textit{T} is shorter than about 1.0 second. When \textit{T} is longer than about 1.0 second, the deviations are mostly plus. Earthquakes in both regions show the same tendency, but the boundary shifts to 1.2 - 1.4 seconds.

As shown in figure 4, \textit{mb} values determined at Matsushiro are smaller than those of NOAA for explosions in Kazakh, but this relation is reversed for explosions in NTS. These significant deviations are probably due to the response of the employed SP seismograph, which has a sharp maximum magnification at 0.6 second and gives a strong filtering effect.

Therefore, the maximum trace amplitude on the seismogram does not necessarily mean the maximum ground amplitude. Broad-band seismographs will be more adequate to receive information from the source without much distortion.

5. \textit{Ms}

\textit{Ms} values determined at Matsushiro have no such deviations from NOAA values as in the case of \textit{mb} values. The detection capability at Matsushiro for surface waves by the LP seismograph is, of course, lower than that by SP for P waves. It scarcely detects surface waves from events of \textit{Ms}:5.0 in NTS and those of \textit{Ms}:4.5 in Kazakh.
6. Difference of P-wave spectra between earthquakes and explosions

Two explosions and three earthquakes shown in table 2 are analysed by the Fourier analysis method. The analogue records are shown in figure 5 and the spectra in figure 6.

The spectra of explosions have a strong peak at a higher frequency and a relatively simple pattern, as easily suspected from the analogue records. It is also remarkable that the spectra of explosions in NTS and Aleutian appear very similar. On the other hand, for earthquakes, the spectra are more complicated and appear very different from those of explosions.

7. mb versus Ms for explosions and earthquakes

It is well known that Ms of explosions is smaller than that of earthquakes for the same mb. In re-examining Matsushiro data, it is also possible to distinguish explosions from earthquakes by Ms (MAT) and mb (MOAA) with a good separation, as shown in figure 7. Ms of small explosions, however, is presently difficult to determine at Matsushiro because of a low magnification of the LP seismograph. The newly installed LP seismograph of very high magnification (HGLP of NOAA) will certainly enhance the detection capability of MAT for surface waves.

Since the standard deviation of mb values is larger than that of Ms values, mb should be determined by data from as many stations as possible, whereas Ms, which seems more stable, may be determined at a fewer number of stations, when the mb:Ms criterion is employed.
### Table 1

**List of events**

Presumed and announced underground explosions and earthquakes in and near Kazakh and the Nevada Test Site

**USSR presumed explosion**

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time (G.M.T.)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Km</th>
<th>NOAA</th>
<th>MAT</th>
<th>Dist.</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 Feb. 66</td>
<td>04 57 57.9</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>6.2</td>
<td>-</td>
<td>5.7</td>
<td>44.6</td>
</tr>
<tr>
<td>27 Oct. 66</td>
<td>05 57 57.7</td>
<td>73.4</td>
<td>54.9</td>
<td>0</td>
<td>6.3</td>
<td>-</td>
<td>Sat</td>
<td>5.2</td>
</tr>
<tr>
<td>17 Oct. 67</td>
<td>05 03 58.0</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>5.7</td>
<td>-</td>
<td>5.1</td>
<td>44.6</td>
</tr>
<tr>
<td>21 Oct. 67</td>
<td>04 59 58.1</td>
<td>73.4</td>
<td>54.8</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>4.5</td>
<td>53.5</td>
</tr>
<tr>
<td>29 Sept. 68</td>
<td>03 42 57.5</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>5.6</td>
<td>44.6</td>
</tr>
<tr>
<td>7 Nov. 68</td>
<td>10 02 05.3</td>
<td>73.4</td>
<td>54.9</td>
<td>0</td>
<td>6.0</td>
<td>-</td>
<td>6.0</td>
<td>4.7</td>
</tr>
<tr>
<td>7 Mar. 69</td>
<td>08 26 57.5</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.0</td>
<td>44.6</td>
</tr>
<tr>
<td>16 May 69</td>
<td>04 02 57.1</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>4.8</td>
<td>3.5</td>
</tr>
<tr>
<td>31 May 69</td>
<td>05 01 56.6</td>
<td>50.0</td>
<td>77.7</td>
<td>0</td>
<td>5.4</td>
<td>-</td>
<td>5.1</td>
<td>44.9</td>
</tr>
<tr>
<td>4 July 69</td>
<td>02 46 57.0</td>
<td>49.7</td>
<td>78.2</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>4.8</td>
<td>44.6</td>
</tr>
<tr>
<td>23 July 69</td>
<td>02 46 58.1</td>
<td>49.9</td>
<td>78.3</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.1</td>
<td>44.5</td>
</tr>
<tr>
<td>11 Sept. 69</td>
<td>04 01 57.1</td>
<td>49.7</td>
<td>78.1</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>4.7</td>
<td>44.6</td>
</tr>
<tr>
<td>26 Sept. 69</td>
<td>06 59 55.8</td>
<td>45.9</td>
<td>42.5</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.9</td>
<td>48.4</td>
</tr>
<tr>
<td>1 Oct. 69</td>
<td>04 02 57.6</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>4.7</td>
<td>44.6</td>
</tr>
<tr>
<td>14 Oct. 69</td>
<td>07 00 06.2</td>
<td>73.4</td>
<td>54.8</td>
<td>0</td>
<td>6.1</td>
<td>-</td>
<td>6.1</td>
<td>4.8</td>
</tr>
<tr>
<td>30 Nov. 69</td>
<td>03 32 57.2</td>
<td>49.9</td>
<td>79.0</td>
<td>0</td>
<td>6.0</td>
<td>-</td>
<td>5.9</td>
<td>44.0</td>
</tr>
<tr>
<td>6 Dec. 69</td>
<td>07 02 57.4</td>
<td>43.8</td>
<td>54.8</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>6.2</td>
<td>4.4</td>
</tr>
<tr>
<td>28 Dec. 69</td>
<td>03 46 58.0</td>
<td>50.0</td>
<td>77.8</td>
<td>0</td>
<td>5.7</td>
<td>-</td>
<td>5.6</td>
<td>44.8</td>
</tr>
<tr>
<td>29 Jan. 70</td>
<td>07 02 57.5</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>28 June 70</td>
<td>01 57 57.7</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.9</td>
<td>-</td>
<td>5.1</td>
<td>44.6</td>
</tr>
<tr>
<td>21 July 70</td>
<td>03 02 57.1</td>
<td>50.0</td>
<td>77.8</td>
<td>0</td>
<td>5.4</td>
<td>-</td>
<td>5.2</td>
<td>44.8</td>
</tr>
<tr>
<td>24 July 70</td>
<td>03 56 57.4</td>
<td>49.8</td>
<td>78.2</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>4.8</td>
<td>44.6</td>
</tr>
<tr>
<td>6 Sept. 70</td>
<td>04 02 57.4</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.1</td>
<td>44.6</td>
</tr>
<tr>
<td>14 Oct. 70</td>
<td>05 59 57.1</td>
<td>73.3</td>
<td>55.1</td>
<td>0</td>
<td>6.7</td>
<td>5.1</td>
<td>Sat</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time (G.M.T.)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth</th>
<th>NOAA mb</th>
<th>MAT mb</th>
<th>Dist. Km</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 70</td>
<td>06 02 57.0</td>
<td>50.0</td>
<td>77.8</td>
<td>0</td>
<td>5.4</td>
<td>-</td>
<td>44.8</td>
<td>52.8</td>
</tr>
<tr>
<td>17 Dec. 70</td>
<td>07 00 57.4</td>
<td>49.7</td>
<td>78.1</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>44.6</td>
<td>53.2</td>
</tr>
<tr>
<td>12 Dec. 70</td>
<td>07 00 57.3</td>
<td>43.9</td>
<td>54.8</td>
<td>0</td>
<td>6.1</td>
<td>-</td>
<td>61.5</td>
<td>54.8</td>
</tr>
<tr>
<td>23 Dec. 70</td>
<td>07 00 57.3</td>
<td>43.8</td>
<td>54.8</td>
<td>0</td>
<td>6.1</td>
<td>-</td>
<td>61.6</td>
<td>54.9</td>
</tr>
<tr>
<td>22 Mar. 71</td>
<td>04 32 57.8</td>
<td>49.7</td>
<td>78.2</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>44.6</td>
<td>53.2</td>
</tr>
<tr>
<td>23 Mar. 71</td>
<td>06 59 56.0</td>
<td>61.3</td>
<td>56.5</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>54.9</td>
<td>35.7</td>
</tr>
<tr>
<td>25 Apr. 71</td>
<td>03 32 58.0</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>5.9</td>
<td>-</td>
<td>44.6</td>
<td>53.1</td>
</tr>
<tr>
<td>6 June 71</td>
<td>04 02 57.1</td>
<td>50.0</td>
<td>77.8</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>44.8</td>
<td>52.8</td>
</tr>
<tr>
<td>19 June 71</td>
<td>04 03 57.6</td>
<td>50.0</td>
<td>77.7</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>44.9</td>
<td>52.8</td>
</tr>
<tr>
<td>30 June 71</td>
<td>03 56 57.2</td>
<td>50.0</td>
<td>77.1</td>
<td>0</td>
<td>5.4</td>
<td>-</td>
<td>44.0</td>
<td>52.9</td>
</tr>
<tr>
<td>10 July 71</td>
<td>16 59 59.3</td>
<td>64.2</td>
<td>55.2</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>54.8</td>
<td>32.1</td>
</tr>
<tr>
<td>9 Oct. 71</td>
<td>06 02 57.1</td>
<td>50.0</td>
<td>77.7</td>
<td>0</td>
<td>5.4</td>
<td>-</td>
<td>44.9</td>
<td>52.8</td>
</tr>
<tr>
<td>21 Oct. 71</td>
<td>06 02 57.3</td>
<td>50.0</td>
<td>77.6</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>44.9</td>
<td>52.8</td>
</tr>
<tr>
<td>22 Dec. 71</td>
<td>06 59 56.3</td>
<td>47.9</td>
<td>48.2</td>
<td>0</td>
<td>6.0</td>
<td>-</td>
<td>64.0</td>
<td>48.5</td>
</tr>
<tr>
<td>30 Dec. 71</td>
<td>06 20 57.7</td>
<td>49.8</td>
<td>78.1</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>53.3</td>
<td>53.1</td>
</tr>
<tr>
<td>10 Feb. 72</td>
<td>05 02 57.0</td>
<td>49.0</td>
<td>79.0</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>44.1</td>
<td>54.3</td>
</tr>
</tbody>
</table>

Nevada test site explosion

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time (G.M.T.)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth</th>
<th>NOAA mb</th>
<th>MAT mb</th>
<th>Dist. Km</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 Apr. 68</td>
<td>15 00 00.1</td>
<td>37.3</td>
<td>-116.5</td>
<td>0</td>
<td>6.3</td>
<td>-</td>
<td>7.1</td>
<td>5.3</td>
</tr>
<tr>
<td>6 Sept. 68</td>
<td>14 00 00.1</td>
<td>37.2</td>
<td>-116.5</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.9</td>
<td>79.8</td>
</tr>
<tr>
<td>19 Dec. 68</td>
<td>16 30 00.0</td>
<td>37.2</td>
<td>-116.5</td>
<td>0</td>
<td>6.3</td>
<td>5.6</td>
<td>6.8</td>
<td>5.4</td>
</tr>
<tr>
<td>15 Jan. 69</td>
<td>19 30 00.0</td>
<td>37.2</td>
<td>-116.2</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>5.7</td>
<td>79.6</td>
</tr>
<tr>
<td>30 Jan. 69</td>
<td>15 00 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>4.8</td>
<td>-</td>
<td>4.8</td>
<td>79.6</td>
</tr>
<tr>
<td>20 Mar. 69</td>
<td>18 12 00.0</td>
<td>37.0</td>
<td>-116.0</td>
<td>0</td>
<td>4.6</td>
<td>-</td>
<td>5.4</td>
<td>79.7</td>
</tr>
<tr>
<td>30 Apr. 69</td>
<td>17 00 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>5.5</td>
<td>79.6</td>
</tr>
<tr>
<td>7 May 69</td>
<td>13 45 00.0</td>
<td>37.3</td>
<td>-116.5</td>
<td>0</td>
<td>5.8</td>
<td>-</td>
<td>5.9</td>
<td>79.8</td>
</tr>
<tr>
<td>27 May 69</td>
<td>14 15 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>5.2</td>
<td>79.6</td>
</tr>
<tr>
<td>16 July 69</td>
<td>13 02 30.4</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>4.7</td>
<td>-</td>
<td>4.9</td>
<td>79.6</td>
</tr>
<tr>
<td>16 July 69</td>
<td>14 55 00.0</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.7</td>
<td>79.6</td>
</tr>
<tr>
<td>Date</td>
<td>Origin time (G.M.T.)</td>
<td>Lat.</td>
<td>Long.</td>
<td>Depth</td>
<td>NOAA</td>
<td>MAT</td>
<td>Dist.</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>----------------------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
<td>------</td>
<td>-----</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>16 Sept. 69</td>
<td>14 30 00.0</td>
<td>37.3</td>
<td>-116.5</td>
<td>0</td>
<td>6.2</td>
<td>5.1</td>
<td>6.8</td>
<td>5.1</td>
</tr>
<tr>
<td>8 Oct. 69</td>
<td>14 30 00.0</td>
<td>37.3</td>
<td>-116.5</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>29 Oct. 69</td>
<td>19 30 00.0</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.1</td>
<td>-</td>
<td>5.0</td>
<td>-</td>
</tr>
<tr>
<td>29 Oct. 69</td>
<td>20 00 00.0</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>29 Oct. 69</td>
<td>22 01 51.4</td>
<td>37.2</td>
<td>-116.1</td>
<td>0</td>
<td>5.7</td>
<td>-</td>
<td>5.9</td>
<td>-</td>
</tr>
<tr>
<td>21 Nov. 69</td>
<td>14 52 00.0</td>
<td>37.0</td>
<td>-116.0</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>5.0</td>
<td>-</td>
</tr>
<tr>
<td>5 Dec. 69</td>
<td>17 00 00.0</td>
<td>37.2</td>
<td>-116.2</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>17 Dec. 69</td>
<td>15 00 00.0</td>
<td>37.0</td>
<td>-116.0</td>
<td>0</td>
<td>4.8</td>
<td>-</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>18 Dec. 69</td>
<td>29 00 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.2</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>4 Feb. 70</td>
<td>17 00 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>6.1</td>
<td>-</td>
</tr>
<tr>
<td>26 Feb. 70</td>
<td>15 30 00.0</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>23 Mar. 70</td>
<td>23 05 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>26 Mar. 70</td>
<td>19 00 00.2</td>
<td>37.3</td>
<td>-116.5</td>
<td>0</td>
<td>6.5</td>
<td>5.3</td>
<td>6.9</td>
<td>5.1</td>
</tr>
<tr>
<td>5 May 70</td>
<td>15 30 00.2</td>
<td>37.2</td>
<td>-116.2</td>
<td>0</td>
<td>5.2</td>
<td>-</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>15 May 70</td>
<td>13 30 00.0</td>
<td>37.2</td>
<td>-116.0</td>
<td>0</td>
<td>5.3</td>
<td>-</td>
<td>5.3</td>
<td>-</td>
</tr>
<tr>
<td>21 May 70</td>
<td>14 15 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.1</td>
<td>-</td>
<td>4.9</td>
<td>-</td>
</tr>
<tr>
<td>26 May 70</td>
<td>14 16 00.2</td>
<td>37.2</td>
<td>-116.2</td>
<td>0</td>
<td>5.0</td>
<td>-</td>
<td>4.9</td>
<td>-</td>
</tr>
<tr>
<td>26 May 70</td>
<td>15 00 00.0</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.6</td>
<td>-</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>14 Oct. 70</td>
<td>14 30 00.0</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.8</td>
<td>-</td>
</tr>
<tr>
<td>16 Dec. 70</td>
<td>16 00 00.1</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.1</td>
<td>-</td>
<td>5.3</td>
<td>-</td>
</tr>
<tr>
<td>17 Dec. 70</td>
<td>16 05 00.2</td>
<td>37.1</td>
<td>-116.1</td>
<td>0</td>
<td>5.7</td>
<td>-</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>18 Dec. 70</td>
<td>15 30 00.2</td>
<td>37.2</td>
<td>-116.1</td>
<td>0</td>
<td>5.2</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>23 June 71</td>
<td>15 30 00.0</td>
<td>37.0</td>
<td>-116.0</td>
<td>0</td>
<td>4.8</td>
<td>-</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>24 June 71</td>
<td>14 00 00.2</td>
<td>37.2</td>
<td>-116.1</td>
<td>0</td>
<td>5.2</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>8 July 71</td>
<td>14 00 00.1</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>5.5</td>
<td>-</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>8 Oct. 71</td>
<td>14 30 00.1</td>
<td>37.1</td>
<td>-116.0</td>
<td>0</td>
<td>4.7</td>
<td>-</td>
<td>4.5</td>
<td>-</td>
</tr>
</tbody>
</table>

**USSR Earthquake**

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth</th>
<th>NOAA</th>
<th>MAT</th>
<th>Dist.</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 Jan. 70</td>
<td>00 31 52.6</td>
<td>41.1</td>
<td>69.3</td>
<td>43</td>
<td>5.0</td>
<td>-</td>
<td>5.2</td>
</tr>
<tr>
<td>6 Feb. 70</td>
<td>22 10 41.6</td>
<td>23.1</td>
<td>100.8</td>
<td>33</td>
<td>5.4</td>
<td>6.1</td>
<td>5.6</td>
</tr>
</tbody>
</table>

-157-
Table 1 (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time (G.M.T.)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth Km</th>
<th>NOAA mb</th>
<th>Ms</th>
<th>MAT mb</th>
<th>Ms</th>
<th>Dist. Km</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 Feb. 70</td>
<td>07 10 01.8</td>
<td>27.4</td>
<td>94.0</td>
<td>18</td>
<td>5.5</td>
<td>-</td>
<td>5.7</td>
<td>5.1</td>
<td>38.3</td>
<td>90.8</td>
</tr>
<tr>
<td>10 Mar. 70</td>
<td>05 20 10.3</td>
<td>26.8</td>
<td>97.0</td>
<td>33</td>
<td>5.4</td>
<td>-</td>
<td>5.2</td>
<td>-</td>
<td>36.2</td>
<td>93.6</td>
</tr>
<tr>
<td>28 Mar. 70</td>
<td>09 44 57.8</td>
<td>52.2</td>
<td>105.8</td>
<td>33</td>
<td>5.2</td>
<td>-</td>
<td>4.8</td>
<td>4.3</td>
<td>27.7</td>
<td>45.3</td>
</tr>
<tr>
<td>23 Apr. 70</td>
<td>18 02 18.8</td>
<td>37.5</td>
<td>72.6</td>
<td>46</td>
<td>5.1</td>
<td>-</td>
<td>5.0</td>
<td>4.3</td>
<td>51.4</td>
<td>67.9</td>
</tr>
<tr>
<td>15 May 70</td>
<td>17 13 15.1</td>
<td>50.2</td>
<td>91.3</td>
<td>33</td>
<td>5.9</td>
<td>6.7</td>
<td>6.0</td>
<td>-</td>
<td>36.1</td>
<td>52.8</td>
</tr>
<tr>
<td>5 June 70</td>
<td>04 53 06.4</td>
<td>42.5</td>
<td>78.8</td>
<td>20</td>
<td>6.0</td>
<td>6.6</td>
<td>6.4</td>
<td>-</td>
<td>45.4</td>
<td>63.4</td>
</tr>
<tr>
<td>5 June 70</td>
<td>10 31 54.3</td>
<td>63.4</td>
<td>146.2</td>
<td>33</td>
<td>5.5</td>
<td>5.4</td>
<td>5.4</td>
<td>4.7</td>
<td>27.3</td>
<td>392.2</td>
</tr>
<tr>
<td>29 July 70</td>
<td>05 50 56.4</td>
<td>39.9</td>
<td>77.8</td>
<td>13</td>
<td>5.2</td>
<td>5.5</td>
<td>5.3</td>
<td>5.3</td>
<td>46.8</td>
<td>66.6</td>
</tr>
<tr>
<td>30 July 70</td>
<td>00 52 19.5</td>
<td>37.8</td>
<td>55.9</td>
<td>19</td>
<td>5.7</td>
<td>6.6</td>
<td>5.9</td>
<td>6.9</td>
<td>63.4</td>
<td>61.4</td>
</tr>
<tr>
<td>31 July 70</td>
<td>13 10 47.4</td>
<td>28.6</td>
<td>103.6</td>
<td>25</td>
<td>5.5</td>
<td>-</td>
<td>4.7</td>
<td>5.0</td>
<td>30.1</td>
<td>95.2</td>
</tr>
<tr>
<td>8 Aug. 70</td>
<td>11 46 31.3</td>
<td>44.3</td>
<td>81.2</td>
<td>33</td>
<td>4.7</td>
<td>-</td>
<td>4.2</td>
<td>4.4</td>
<td>43.3</td>
<td>61.4</td>
</tr>
<tr>
<td>5 Sept. 70</td>
<td>13 37 34.9</td>
<td>32.0</td>
<td>101.2</td>
<td>33</td>
<td>5.0</td>
<td>-</td>
<td>5.0</td>
<td>4.7</td>
<td>30.8</td>
<td>87.5</td>
</tr>
<tr>
<td>18 Sept. 70</td>
<td>20 02 25.0</td>
<td>36.4</td>
<td>68.9</td>
<td>33</td>
<td>5.1</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
<td>54.6</td>
<td>67.9</td>
</tr>
<tr>
<td>7 Oct. 70</td>
<td>02 20 36.7</td>
<td>27.8</td>
<td>56.5</td>
<td>43</td>
<td>5.0</td>
<td>-</td>
<td>4.8</td>
<td>-</td>
<td>67.8</td>
<td>71.2</td>
</tr>
<tr>
<td>9 Oct. 70</td>
<td>13 48 32.6</td>
<td>39.1</td>
<td>71.7</td>
<td>46</td>
<td>5.2</td>
<td>-</td>
<td>5.1</td>
<td>-</td>
<td>51.5</td>
<td>65.7</td>
</tr>
<tr>
<td>15 Oct. 70</td>
<td>03 55 16.1</td>
<td>39.8</td>
<td>77.2</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>5.2</td>
<td>-</td>
<td>47.3</td>
<td>66.6</td>
</tr>
<tr>
<td>25 Oct. 70</td>
<td>11 22 18.2</td>
<td>36.8</td>
<td>45.1</td>
<td>19</td>
<td>5.5</td>
<td>4.8</td>
<td>4.5</td>
<td>4.8</td>
<td>71.2</td>
<td>57.7</td>
</tr>
<tr>
<td>2 Feb. 71</td>
<td>07 59 57.0</td>
<td>23.0</td>
<td>91.8</td>
<td>48</td>
<td>5.4</td>
<td>-</td>
<td>4.8</td>
<td>4.4</td>
<td>41.7</td>
<td>94.4</td>
</tr>
<tr>
<td>23 Feb. 71</td>
<td>19 41 23.0</td>
<td>39.6</td>
<td>27.4</td>
<td>15</td>
<td>5.0</td>
<td>5.4</td>
<td>5.6</td>
<td>5.3</td>
<td>81.1</td>
<td>47.0</td>
</tr>
<tr>
<td>23 Mar. 71</td>
<td>09 52 12.3</td>
<td>41.5</td>
<td>79.3</td>
<td>33</td>
<td>5.7</td>
<td>-</td>
<td>5.4</td>
<td>-</td>
<td>45.3</td>
<td>64.9</td>
</tr>
<tr>
<td>24 Mar. 71</td>
<td>13 54 17.7</td>
<td>35.5</td>
<td>98.2</td>
<td>13</td>
<td>5.8</td>
<td>6.4</td>
<td>6.2</td>
<td>6.0</td>
<td>32.3</td>
<td>79.7</td>
</tr>
<tr>
<td>24 Mar. 71</td>
<td>20 54 28.6</td>
<td>41.5</td>
<td>79.5</td>
<td>18</td>
<td>5.3</td>
<td>-</td>
<td>4.8</td>
<td>4.6</td>
<td>45.1</td>
<td>64.9</td>
</tr>
<tr>
<td>24 Mar. 71</td>
<td>21 01 54.9</td>
<td>41.4</td>
<td>79.4</td>
<td>25</td>
<td>5.3</td>
<td>-</td>
<td>5.0</td>
<td>-</td>
<td>45.2</td>
<td>65.0</td>
</tr>
<tr>
<td>28 Mar. 71</td>
<td>02 54 12.2</td>
<td>19.1</td>
<td>96.3</td>
<td>34</td>
<td>4.4</td>
<td>-</td>
<td>4.6</td>
<td>-</td>
<td>40.6</td>
<td>103.8</td>
</tr>
<tr>
<td>31 Mar. 71</td>
<td>08 16 19.6</td>
<td>26.2</td>
<td>96.6</td>
<td>22</td>
<td>5.0</td>
<td>-</td>
<td>4.7</td>
<td>5.2</td>
<td>36.7</td>
<td>94.3</td>
</tr>
<tr>
<td>3 Apr. 71</td>
<td>04 49 03.4</td>
<td>32.3</td>
<td>95.1</td>
<td>33</td>
<td>5.7</td>
<td>-</td>
<td>5.8</td>
<td>6.4</td>
<td>35.6</td>
<td>83.9</td>
</tr>
<tr>
<td>3 Apr. 71</td>
<td>04 50 45.6</td>
<td>32.3</td>
<td>95.4</td>
<td>33</td>
<td>5.8</td>
<td>-</td>
<td>5.5</td>
<td>-</td>
<td>35.4</td>
<td>84.1</td>
</tr>
<tr>
<td>6 Apr. 71</td>
<td>06 49 52.9</td>
<td>29.8</td>
<td>51.9</td>
<td>10</td>
<td>5.2</td>
<td>5.1</td>
<td>5.2</td>
<td>5.3</td>
<td>70.2</td>
<td>67.2</td>
</tr>
<tr>
<td>12 Apr. 71</td>
<td>19 03 25.9</td>
<td>28.3</td>
<td>55.6</td>
<td>44</td>
<td>6.0</td>
<td>5.9</td>
<td>5.8</td>
<td>5.8</td>
<td>68.2</td>
<td>70.3</td>
</tr>
<tr>
<td>13 Apr. 71</td>
<td>12 52 34.6</td>
<td>39.0</td>
<td>29.9</td>
<td>13</td>
<td>5.1</td>
<td>-</td>
<td>5.1</td>
<td>5.3</td>
<td>80.0</td>
<td>48.7</td>
</tr>
<tr>
<td>28 Apr. 71</td>
<td>15 32 00.9</td>
<td>22.9</td>
<td>101.0</td>
<td>15</td>
<td>5.6</td>
<td>6.3</td>
<td>4.7</td>
<td>-</td>
<td>34.8</td>
<td>102.5</td>
</tr>
<tr>
<td>Date</td>
<td>Origin time (G.M.T.)</td>
<td>Lat.</td>
<td>Long.</td>
<td>Depth Km</td>
<td>NOAA mb</td>
<td>Ms mb</td>
<td>MAT Ms</td>
<td>Dist. Km</td>
<td>AZIM</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------------</td>
<td>------</td>
<td>-------</td>
<td>----------</td>
<td>---------</td>
<td>-------</td>
<td>--------</td>
<td>----------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>3 May 71</td>
<td>00 33 22.5</td>
<td>30.8</td>
<td>84.5</td>
<td>16</td>
<td>5.4</td>
<td>-</td>
<td>5.0</td>
<td>44.6</td>
<td>81.1</td>
<td></td>
</tr>
<tr>
<td>10 May 71</td>
<td>14 51 46.8</td>
<td>42.8</td>
<td>71.4</td>
<td>33</td>
<td>5.6</td>
<td>5.4</td>
<td>6.0</td>
<td>50.6</td>
<td>61.1</td>
<td></td>
</tr>
<tr>
<td>12 May 71</td>
<td>06 25 13.0</td>
<td>37.6</td>
<td>29.8</td>
<td>23</td>
<td>5.5</td>
<td>5.9</td>
<td>5.6</td>
<td>80.9</td>
<td>49.8</td>
<td></td>
</tr>
<tr>
<td>12 May 71</td>
<td>10 10 37.2</td>
<td>37.5</td>
<td>29.7</td>
<td>33</td>
<td>5.5</td>
<td>-</td>
<td>5.5</td>
<td>81.0</td>
<td>49.8</td>
<td></td>
</tr>
<tr>
<td>12 May 71</td>
<td>12 57 24.8</td>
<td>37.6</td>
<td>29.6</td>
<td>33</td>
<td>5.4</td>
<td>5.2</td>
<td>5.3</td>
<td>81.0</td>
<td>49.6</td>
<td></td>
</tr>
<tr>
<td>22 May 71</td>
<td>16 43 58.7</td>
<td>38.8</td>
<td>40.5</td>
<td>3</td>
<td>6.0</td>
<td>6.7</td>
<td>6.2</td>
<td>73.4</td>
<td>53.9</td>
<td></td>
</tr>
<tr>
<td>22 May 71</td>
<td>20 03 32.4</td>
<td>32.4</td>
<td>92.1</td>
<td>33</td>
<td>5.6</td>
<td>6.1</td>
<td>5.9</td>
<td>38.0</td>
<td>82.4</td>
<td></td>
</tr>
<tr>
<td>25 May 71</td>
<td>05 43 27.0</td>
<td>39.0</td>
<td>29.7</td>
<td>24</td>
<td>5.8</td>
<td>5.5</td>
<td>5.9</td>
<td>80.1</td>
<td>48.6</td>
<td></td>
</tr>
<tr>
<td>26 May 71</td>
<td>02 41 46.0</td>
<td>35.5</td>
<td>58.2</td>
<td>26</td>
<td>5.4</td>
<td>5.4</td>
<td>5.8</td>
<td>62.8</td>
<td>64.6</td>
<td></td>
</tr>
<tr>
<td>30 May 71</td>
<td>11 55 59.9</td>
<td>25.3</td>
<td>96.4</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>5.4</td>
<td>37.3</td>
<td>95.5</td>
<td></td>
</tr>
<tr>
<td>30 May 71</td>
<td>15 44 15.7</td>
<td>25.2</td>
<td>96.4</td>
<td>15</td>
<td>5.8</td>
<td>6.1</td>
<td>6.1</td>
<td>37.4</td>
<td>95.6</td>
<td></td>
</tr>
<tr>
<td>30 May 71</td>
<td>21 39 00.5</td>
<td>25.3</td>
<td>94.4</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>5.1</td>
<td>38.9</td>
<td>94.1</td>
<td></td>
</tr>
<tr>
<td>31 May 71</td>
<td>05 13 59.7</td>
<td>25.2</td>
<td>96.5</td>
<td>33</td>
<td>5.3</td>
<td>6.1</td>
<td>6.1</td>
<td>37.3</td>
<td>95.7</td>
<td></td>
</tr>
<tr>
<td>8 June 71</td>
<td>23 42 55.2</td>
<td>37.6</td>
<td>29.7</td>
<td>28</td>
<td>4.8</td>
<td>-</td>
<td>5.1</td>
<td>81.0</td>
<td>49.7</td>
<td></td>
</tr>
<tr>
<td>14 June 71</td>
<td>13 48 55.7</td>
<td>56.2</td>
<td>123.6</td>
<td>33</td>
<td>5.6</td>
<td>5.7</td>
<td>5.6</td>
<td>22.0</td>
<td>22.1</td>
<td></td>
</tr>
<tr>
<td>15 June 71</td>
<td>07 39 37.1</td>
<td>41.5</td>
<td>79.4</td>
<td>33</td>
<td>5.6</td>
<td>-</td>
<td>5.1</td>
<td>45.2</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>15 June 71</td>
<td>22 04 13.4</td>
<td>41.5</td>
<td>79.3</td>
<td>33</td>
<td>5.6</td>
<td>5.6</td>
<td>5.4</td>
<td>45.3</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>16 June 71</td>
<td>00 58 37.4</td>
<td>41.5</td>
<td>79.4</td>
<td>33</td>
<td>5.4</td>
<td>5.5</td>
<td>5.0</td>
<td>45.2</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>19 June 71</td>
<td>17 23 02.7</td>
<td>41.5</td>
<td>79.3</td>
<td>33</td>
<td>5.2</td>
<td>5.3</td>
<td>5.2</td>
<td>45.3</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>28 June 71</td>
<td>05 01 48.6</td>
<td>37.9</td>
<td>106.2</td>
<td>33</td>
<td>5.2</td>
<td>-</td>
<td>4.4</td>
<td>25.5</td>
<td>77.2</td>
<td></td>
</tr>
<tr>
<td>29 June 71</td>
<td>09 08 11.7</td>
<td>37.1</td>
<td>36.8</td>
<td>35</td>
<td>5.0</td>
<td>5.5</td>
<td>5.4</td>
<td>76.8</td>
<td>53.6</td>
<td></td>
</tr>
<tr>
<td>11 July 71</td>
<td>20 12 54.8</td>
<td>37.2</td>
<td>36.8</td>
<td>9</td>
<td>5.2</td>
<td>5.8</td>
<td>4.7</td>
<td>76.7</td>
<td>53.5</td>
<td></td>
</tr>
<tr>
<td>17 July 71</td>
<td>15 00 55.4</td>
<td>26.5</td>
<td>93.2</td>
<td>49</td>
<td>5.3</td>
<td>5.1</td>
<td>5.0</td>
<td>39.3</td>
<td>91.6</td>
<td></td>
</tr>
<tr>
<td>24 July 71</td>
<td>11 43 38.8</td>
<td>39.5</td>
<td>73.2</td>
<td>33</td>
<td>5.6</td>
<td>-</td>
<td>5.4</td>
<td>50.3</td>
<td>65.7</td>
<td></td>
</tr>
<tr>
<td>5 Aug. 71</td>
<td>22 37 10.9</td>
<td>12.6</td>
<td>94.8</td>
<td>31</td>
<td>5.0</td>
<td>-</td>
<td>5.4</td>
<td>45.6</td>
<td>110.1</td>
<td></td>
</tr>
<tr>
<td>7 Aug. 71</td>
<td>15 21 52.5</td>
<td>36.1</td>
<td>77.7</td>
<td>33</td>
<td>4.8</td>
<td>-</td>
<td>4.8</td>
<td>48.0</td>
<td>71.5</td>
<td></td>
</tr>
<tr>
<td>16 Aug. 71</td>
<td>04 58 00.3</td>
<td>28.9</td>
<td>103.7</td>
<td>33</td>
<td>5.5</td>
<td>-</td>
<td>5.2</td>
<td>29.9</td>
<td>94.7</td>
<td></td>
</tr>
<tr>
<td>16 Aug. 71</td>
<td>18 53 54.7</td>
<td>28.9</td>
<td>103.7</td>
<td>33</td>
<td>5.3</td>
<td>5.6</td>
<td>5.1</td>
<td>29.9</td>
<td>94.7</td>
<td></td>
</tr>
<tr>
<td>16 Aug. 71</td>
<td>22 37 33.6</td>
<td>28.8</td>
<td>103.6</td>
<td>33</td>
<td>5.4</td>
<td>-</td>
<td>5.1</td>
<td>30.0</td>
<td>94.8</td>
<td></td>
</tr>
<tr>
<td>17 Aug. 71</td>
<td>09 36 45.5</td>
<td>28.9</td>
<td>103.7</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>4.6</td>
<td>29.9</td>
<td>94.7</td>
<td></td>
</tr>
<tr>
<td>17 Aug. 71</td>
<td>17 07 40.4</td>
<td>28.9</td>
<td>103.7</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>4.4</td>
<td>29.9</td>
<td>94.7</td>
<td></td>
</tr>
</tbody>
</table>
## Table 1 (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time (G.M.T.)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth Km</th>
<th>NOAA mb</th>
<th>MAT Ms</th>
<th>Dist. Km</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 Aug. 71</td>
<td>05 36 11.4</td>
<td>28.8</td>
<td>103.7</td>
<td>33</td>
<td>5.2</td>
<td>-</td>
<td>4.7</td>
<td>29.9</td>
</tr>
<tr>
<td>2 Sept. 71</td>
<td>18 24 47.3</td>
<td>30.1</td>
<td>50.8</td>
<td>45</td>
<td>5.1</td>
<td>-</td>
<td>4.9</td>
<td>70.9</td>
</tr>
<tr>
<td>2 Sept. 71</td>
<td>22 21 39.0</td>
<td>30.1</td>
<td>50.8</td>
<td>39</td>
<td>5.0</td>
<td>-</td>
<td>4.8</td>
<td>70.9</td>
</tr>
<tr>
<td>4 Sept. 71</td>
<td>01 10 33.0</td>
<td>29.0</td>
<td>103.7</td>
<td>33</td>
<td>5.0</td>
<td>-</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>6 Sept. 71</td>
<td>00 33 25.9</td>
<td>33.2</td>
<td>69.9</td>
<td>37</td>
<td>4.9</td>
<td>-</td>
<td>5.0</td>
<td>55.1</td>
</tr>
<tr>
<td>28 Oct. 71</td>
<td>13 30 57.1</td>
<td>41.9</td>
<td>72.4</td>
<td>22</td>
<td>5.5</td>
<td>-</td>
<td>5.5</td>
<td>5.1</td>
</tr>
<tr>
<td>29 Oct. 71</td>
<td>17 16 52.1</td>
<td>34.1</td>
<td>86.3</td>
<td>33</td>
<td>5.0</td>
<td>-</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>6 Nov. 71</td>
<td>19 43 46.8</td>
<td>39.0</td>
<td>29.7</td>
<td>16</td>
<td>5.0</td>
<td>-</td>
<td>5.1</td>
<td>4.6</td>
</tr>
<tr>
<td>8 Nov. 71</td>
<td>03 06 36.4</td>
<td>27.1</td>
<td>54.5</td>
<td>36</td>
<td>5.6</td>
<td>5.9</td>
<td>5.8</td>
<td>5.8</td>
</tr>
<tr>
<td>18 Nov. 71</td>
<td>07 31 32.8</td>
<td>38.3</td>
<td>66.8</td>
<td>30</td>
<td>5.3</td>
<td>-</td>
<td>5.8</td>
<td>4.9</td>
</tr>
<tr>
<td>19 Nov. 71</td>
<td>01 00 01.0</td>
<td>41.9</td>
<td>72.4</td>
<td>33</td>
<td>4.9</td>
<td>-</td>
<td>5.1</td>
<td>4.6</td>
</tr>
</tbody>
</table>

### California Earthquake

<table>
<thead>
<tr>
<th>Date</th>
<th>Origin time</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth</th>
<th>NOAA mb</th>
<th>MAT Ms</th>
<th>Dist. Km</th>
<th>AZIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Mar. 69</td>
<td>08 17 41.9</td>
<td>31.3</td>
<td>-114.3</td>
<td>20</td>
<td>5.4</td>
<td>5.7</td>
<td>6.0</td>
<td>5.6</td>
</tr>
<tr>
<td>21 Mar. 69</td>
<td>03 53 42.4</td>
<td>31.2</td>
<td>-114.2</td>
<td>33</td>
<td>5.3</td>
<td>5.0</td>
<td>5.9</td>
<td>5.2</td>
</tr>
<tr>
<td>21 Mar. 69</td>
<td>04 56 20.3</td>
<td>31.2</td>
<td>-114.2</td>
<td>33</td>
<td>5.4</td>
<td>5.5</td>
<td>6.1</td>
<td>5.6</td>
</tr>
<tr>
<td>21 Mar. 69</td>
<td>06 34 22.2</td>
<td>31.1</td>
<td>-116.2</td>
<td>4</td>
<td>5.5</td>
<td>5.4</td>
<td>5.8</td>
<td>5.5</td>
</tr>
<tr>
<td>21 Mar. 69</td>
<td>07 21 11.6</td>
<td>31.3</td>
<td>-114.2</td>
<td>33</td>
<td>5.1</td>
<td>5.2</td>
<td>5.7</td>
<td>5.4</td>
</tr>
<tr>
<td>21 Mar. 69</td>
<td>10 10 10.7</td>
<td>31.2</td>
<td>-114.2</td>
<td>5</td>
<td>5.4</td>
<td>4.9</td>
<td>5.9</td>
<td>5.2</td>
</tr>
<tr>
<td>24 Mar. 69</td>
<td>09 02 32.1</td>
<td>31.3</td>
<td>-114.2</td>
<td>25</td>
<td>4.9</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>28 Apr. 69</td>
<td>23 20 42.9</td>
<td>33.4</td>
<td>-116.4</td>
<td>20</td>
<td>5.7</td>
<td>5.2</td>
<td>5.9</td>
<td>5.2</td>
</tr>
<tr>
<td>17 Aug. 69</td>
<td>20 14 58.9</td>
<td>25.0</td>
<td>-109.5</td>
<td>33</td>
<td>6.1</td>
<td>6.6</td>
<td>6.0</td>
<td>6.8</td>
</tr>
<tr>
<td>18 Aug. 69</td>
<td>03 21 44.0</td>
<td>24.9</td>
<td>-109.0</td>
<td>22</td>
<td>5.3</td>
<td>5.5</td>
<td>5.9</td>
<td>5.6</td>
</tr>
<tr>
<td>18 Aug. 69</td>
<td>03 54 49.8</td>
<td>24.8</td>
<td>-109.1</td>
<td>33</td>
<td>5.3</td>
<td>5.2</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>21 Aug. 69</td>
<td>14 25 51.5</td>
<td>23.2</td>
<td>-110.6</td>
<td>15</td>
<td>5.3</td>
<td>5.2</td>
<td>6.1</td>
<td>5.2</td>
</tr>
<tr>
<td>1 Nov. 69</td>
<td>11 08 20.9</td>
<td>23.1</td>
<td>-107.9</td>
<td>33</td>
<td>5.6</td>
<td>6.6</td>
<td>6.2</td>
<td>6.5</td>
</tr>
<tr>
<td>5 Nov. 69</td>
<td>17 54 13.6</td>
<td>34.8</td>
<td>-121.2</td>
<td>33</td>
<td>5.8</td>
<td>5.8</td>
<td>6.3</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Table 2
List of events used for P-wave Fourier analyses

<table>
<thead>
<tr>
<th>No.</th>
<th>Region</th>
<th>Origin (Z)</th>
<th>Lat.</th>
<th>Long.</th>
<th>Depth (Km)</th>
<th>NOAA mb</th>
<th>Ms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nevada Test Site (explosion)</td>
<td>26 Mar. 1970 190000.2</td>
<td>37.3°N</td>
<td>116.5°W</td>
<td>0</td>
<td>6.5</td>
<td>5.3</td>
</tr>
<tr>
<td>2</td>
<td>RAT Island (explosion)</td>
<td>6 Nov. 1970 220000.1</td>
<td>51.5°N</td>
<td>179.1°E</td>
<td>2</td>
<td>6.8</td>
<td>5.7</td>
</tr>
<tr>
<td>3</td>
<td>Eastern Caucasus</td>
<td>14 May 1970 181228.0</td>
<td>43.0°N</td>
<td>47.1°E</td>
<td>44</td>
<td>5.6</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>USSR-Mongolia Border</td>
<td>15 May 1970 171315.1</td>
<td>50.2°N</td>
<td>91.3°E</td>
<td>N</td>
<td>5.9</td>
<td>6.7</td>
</tr>
<tr>
<td>5</td>
<td>Gulf of California</td>
<td>30 Sept. 1971 081754.6</td>
<td>26.8°N</td>
<td>110.8°W</td>
<td>33</td>
<td>5.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>
One figure showing the detected and undetected number of the presumed and announced underground explosions.

* Hatched area shows number of detected explosions.
Figure 2
Relation between T and mb

USA

USSR

○ EARTHQUAKE
● EXPLOSION

<table>
<thead>
<tr>
<th>MB</th>
<th>USA</th>
<th>USSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3

Frequency distribution of T

---

USA

USSR

- EXPLOSION

- EARTHQUAKE

PERIOD
Figure 4

Deviations of mb, (mb (MAT) - mb (NOAA)), versus T

- Kazakh explosions (USSR)
- Nevada Test site explosions (USA)
- Eurasian earthquakes (USSR)
- California earthquakes (USA)
Figure 5
Examples of seismograms recorded at Matsushiro

NO.1

30 s

NO.2

30 s

NO.3

30 s

NO.4

30 s

NO.5

30 s
Examples of spectra

NO 1

Time (sec) vs. Spectrum Amplitude
Figure 6 (2)

NO 2

-168-
Figure 6 (3)

NO 3

0.2
0.4
0.6
0.8
1.0

T

1 2 3 4 5 6 SEC

-169-
Figure 6 (5)

NO 5

1.0
0.8
0.6
0.4
0.2

1 2 3 4 5 6 SEC
Figure 7 (1)

mb versus Ms for explosions and earthquakes

* The mb values are taken from NOAA and the Ms values are determined at Matsushiro.
Figure 7 (2)

- Ms MAT
- USSR

○: earthquakes
★: explosions

mb NOAA

-173-
17. ITALY

Some observations on detection and identification of underground nuclear explosions – prospects of international co-operation (CCD/409)

[Original: English]
[10 July 1973]

The brilliant results that have been obtained in a relatively short time by research groups engaged in the study of underground nuclear explosions, their detection and discrimination, give ground for hope that, if this research were expanded and if international collaboration could be achieved, the element of uncertainty concerning the methods employed would be greatly reduced if not eliminated.

This problem has two aspects which, in our view, are practically inseparable:

(a) Discrimination of events, especially those of low magnitude;

(b) Refinement of recording techniques with a view to obtaining for any given event a generally recognized value (see Japanese working paper CCD/399).  

I. Further studies required to improve discrimination

The best discrimination results to date have been obtained by the $m_b/M_s$ criterion and other methods employing the body wave spectrum complexity function, or a spectral relationship.

The advantages and limitations of these various methods have been described in the Japanese working paper and earlier reports (CCD/306, 44/ CCD/327, 45/ CCD/363/Rev.1 46/). An investigation carried out at the Observatorio Sismico di Roma (M.P.) along mainly continental propagation paths has highlighted the difficulty of discrimination by the $m_b/M_s$ criterion for low-magnitude events whose $M_s$ values cannot be reliably calculated.

The study of earthquakes at a distance of less than 1,000 kilometres with their epicentres located in a highly tectonized area (western Sicily, Ancona (1972) and Skopje) has also revealed marked anomalies in seismic energy propagation in different directions and consequently differences in the $m_b$ values obtained at the various stations in the Mediterranean area. Such differences are reduced and in many cases fall within the limits of accidental errors wherever surface waves $Q$ and $M$ can be employed (especially $M$ because of its marked vertical component).

44/ Ibid., Supplement for 1970, document DC/233, annex C.
45/ Ibid., Supplement for 1971, document DC/234, annex C.
46/ Ibid., Supplement for 1972, document DC/235, annex B.
Thus, the subjects for further research quite clearly remain unchanged:

(a) Study of body-wave propagation in relation to source dimensions, physical nature of the phenomenon which gave rise to the event and geological environments in which the source was located;

(b) Influence of the paths (continental or oceanic) on the surface waves which, in this instance, offer the advantage of being largely independent of the factors mentioned in (a) above;

(c) Research of constantly valid correlations between the magnitude determined at the receiving station and the energy developed at the source;

(d) Possibility of determining as precisely as possible the date of a given phenomenon.

Since these problems are being tackled mainly with the help of experimental data, or at least cannot be tackled without such data, international collaboration is, in our view, essential if we are to strengthen those stations and networks which have been able until now to produce the most valid results and if we are to create a world-wide network which would be homogeneous both geographically and from the standpoint of instrumentation.

II. Refinement of recording techniques

This suggestion is certainly not intended to exclude the contribution - and it is in many instances an indispensable contribution - of what might be termed "traditional" seismic stations, but rather, for example, to resolve many of the problems associated with the imperative need to obtain a widely acceptable mean value for $m_b$.

It must be borne in mind that improved recording techniques and increased instrument sensitivity, while diminishing the usefulness of the contribution of poorly equipped stations, often find strong limitations due to the fact that microseismic noise and traffic impose amplifier attenuation. An example of this is in the Rome Observatory, mentioned earlier, despite filtering devices employed in the last few years.

The orogenesis of the Italian peninsula has created a geological-tectonic situation, which has resulted in very complex microseismic activity producing notable amplitudes and involving wide areas of the spectrum. In view of all this, mobile equipment will be employed in the massif of the Western Alps in the search for a suitable site for the establishment of a highly sensitive station.

Each country collaborating in an international network should establish at least one station (basic or leader station) mainly for the purpose of supplying useful data for the research studies listed above. The instrumentation required would be as follows:
(a) Short-period and long-period seismographs with electronic amplification according to predetermined specifications;

(b) Station site selection aimed at minimizing "noise";

(c) Filtering devices (possible use of) appropriate to instrumentation characteristics;

(d) Recording in analogue on dual sensitivity magnetic tape.

Much of the value of the network would, however, be lost if there were any sizable gaps in the coverage thus obtained. For instance, it would be quite useless in this geographic area without the support of other Mediterranean countries.

Finally, it would be useful for the officials in charge of stations to meet periodically to discuss results and work out agreed guidelines for the up-dating of instrumentation techniques and possible subjects of further research.
1. In recent discussions concerning the possible form and contents of a chemical weapons convention, the creation of a standing organ for the operational support of such a convention has been suggested by several delegations. The subject was first broached in United States working paper CCD/360. 

2. The present working paper contains an elaboration of Netherlands views expressed on this subject in the past and it is submitted with a view to stimulating further discussions on this important aspect of a ban on chemical weapons.

3. The paper is mainly of an illustrative nature. There is a brief description in section II of some organizational aspects of the establishment of a standing organ and section III deals with the functions to be allocated to an international organ as envisaged by the Netherlands delegation. Section III is based on a number of working hypotheses, which could be modified if found to be unsatisfactory. This section is also mainly illustrative, but it could stand on its own if the Conference of the Committee on Disarmament, rather than discussing the concept of an "embryonic IDO", would prefer to focus attention on organizational arrangements in the context of a chemical weapons convention.

II

4. The organ could be constructed along the familiar pattern of many international organizations, that is, a plenary Conference, a Board and a secretariat.

5. Membership of the Conference would raise no problem if the organ would function only in the context of a chemical weapons convention; members would be the parties to the convention. Taken as the nucleus of an international disarmament organization with future responsibilities also in other fields, the organ should be open-ended. Rights and duties of individual members, except for the right of speech, would then have to be limited and determined by their adherence to the treaties (or their review conferences) which specifically provide for certain tasks of the organ.

6. While the Conference, as a rule, would only meet at certain intervals, the Board, whose members would be elected by the Conference, would have to be so organized as to be able to function continuously. The Board's main functions could be envisaged as providing practical guidance to the work of the organ on the basis of a programme to be established by the Conference.

47/ Ibid.
7. The secretariat, headed by an administrator, would consist of a permanent staff and such additional panels of experts as may be required for the performance of ad hoc or highly specialized activities, such as special investigations or technical studies.

III

8. It is assumed that a chemical weapons convention will have an annex containing a list of agents that would specifically be forbidden. (This assumption is based on the insufficient precision of the purpose criterion by itself.) It may be noted that the assumption is consistent with a comprehensive approach towards chemical disarmament as well as with a phased or partial one. The organ would have to do the up-dating of the annex if necessary. Whenever a party would dispose of information which, in its opinion, would require an amendment to the annex, it should notify the Administrator of the organ and furnish him with the information in support of the notification. Appropriate procedures would be needed to enable the Board to amend the annex provisionally, pending a definitive decision to be taken by the Conference.

9. It is assumed that, even under an unconditional prohibition of certain agents, parties will be entitled to keep small quantities of these agents for prophylactic, protective or other peaceful purposes. Parties would undertake to supply to the Administrator on a regular basis all information on the kinds and quantities of the agents concerned and on the purpose of their use. The Administrator should make this information available to all other parties.

10. A provision of a chemical weapons convention for the destruction of existing stockpiles of chemical means of warfare or their diversion to peaceful purposes, should call for the declaration of these stockpiles and for international observation of their destruction or diversion. The Administrator could be the addressee of the declarations, as well as the originator of observational activities, in which experts of the secretariat could take part together with observers from interested parties. The Administrator should keep all parties informed concerning matters pertaining to the destruction or diversion of military stockpiles.

11. A chemical weapons convention will probably contain a non-transfer and a non-assistance clause. The Conference, on its own initiative, or upon recommendation by the Board or by the Administrator, could give guidance for its implementation, for example, by means of import and export regulations.

12. An article of a chemical weapons convention could call for national legislation to ensure the fulfilment of the basic obligations under the convention. Such measures could be reported to the organ and co-ordinated by the organ.

13. Should a chemical weapons convention provide for the exchange of economic data, the organ would be the indicated clearing house for such an exchange.

14. In general, parties could undertake to furnish to the Administrator such information as the Board might request for the performance of its functions and,
in particular, an annual report on the functioning of the convention within their respective territories stating, inter alia, if any activity prohibited under the convention has occurred.

15. Upon decision by the Board, the Administrator could be authorized to request any party to provide complementary or supplementary information regarding any event or circumstance connected with compliance with the convention, setting out his reasons for the request. Parties should undertake to co-operate with the Administrator.

16. This procedure could also be initiated upon a request to the Board by a party.

17. Confidence in the information to be supplied would significantly be enhanced if the Administrator could be given standing authorization to carry out random checks.

18. If reasonable doubts remained whether a party had fully complied with his obligations under the convention, these doubts could only be removed by a special investigation. Such a special investigation should be decided upon by the Board, which would formulate the procedure for the organization and execution of the investigation. As a rule, such investigations would have to be carried out by experts to be appointed by the Board from a list of experts drawn up every year by the Administrator upon recommendation by parties. Parties should undertake to render all assistance to the investigators as necessary for the performance of their duties. A copy of reports resulting from such an investigation should be transmitted to all parties and to the Secretary-General of the United Nations for transmission to the Security Council.

19. A special investigation might also be carried out at the request of a party suspected of having violated the convention or at the request of a party which is of the opinion that certain activities on its territory could give rise to suspicion.

20. The Board might decide, or any party might request, the convening of a special session of the Conference for the purpose of considering the reports resulting from any special investigation. The Conference might make recommendations to the parties and submit reports to the Secretary-General of the United Nations for transmission to the Security Council.

21. If the organ would be available, a chemical weapons convention could dispense with a provision for a review conference.
19. NORWAY

Letter dated 16 July 1973 from the Permanent Representative of Norway to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament transmitting a working paper by the Government of Norway on seismic research at the Norwegian Seismic Array (NORSAR) (CCD/411)

[Original: English]

[31 July 1973]

Enclosed please find a document entitled "Seismic research at the Norwegian Seismic Array (NORSAR)" that I would ask you kindly to have circulated to the States members of the Conference of the Committee on Disarmament. The document represents a contribution to the work undertaken by the group of experts now meeting at Geneva under the auspices of the Conference of the Committee on Disarmament and contains a presentation of two facets of the research conducted by Norwegian seismologists employed by NORSAR.

(Signed) Jens BOYESEN
Ambassador
INTRODUCTION

In this paper two facets are presented of the research that has been going on at the data centre for the Norwegian Seismic Array (NORSAR) located near Oslo:

(a) Research into methods for detecting small seismic events;

(b) Seismic verification research.

The NORSAR project has been sponsored by the United States of America under the over-all direction of the Advanced Research Projects Agency and the technical management of the Electronic Systems Division, Air Force Systems Command, through contract F-19628-70-C-0283 with the Royal Norwegian Council for Scientific and Industrial Research.
Section 1. Research into methods for detecting small seismic events

An array's capability to detect short-period P-waves is ultimately limited by the following factors:

(a) The amplitude and time variability of the ambient noise which exists in the earth at the site of an array;

(b) The potential improvement in effective signal-to-noise ratio (SNR), which can be achieved by combining the outputs of all of the sensors of the array;

(c) The reduction in amplitude of seismic signals of interest caused by data processing and partial lack of signal similarity across an array.

It should also be pointed out that, in any type of seismic surveillance system, there are certain physical limits as to how much computer and analyst time can be allocated to the task of event detection and verification. For a detailed description of NORSAR hardware and software systems which are similar to those of the large aperture array LASA in Montana, United States of America, we refer to a paper by Bungum et al., 1971 (see item 4 in the list of references at the end of the present report).

The research undertaken for solving event detection problems of the type outlined above will be briefly discussed and summarized below.

1.1 Noise-level fluctuations

At NORSAR, a significant trend in seasonal noise-level variations has been observed, and the same holds on a diurnal basis. This simply means that the array's event detection capability is lower during winter than summer time and also lower during the day than the night. In the latter case, there are roughly 20 per cent more events detected during night time. Relevant data on the phenomena are presented and discussed in a recent report (1973) by Bungum and Ringdal (5). Also a similar study for long-period noise is in progress.

An interesting but mostly ignored aspect of noise-level fluctuations is that the statistical properties of the background noise changes too. This explains why the number of times the Detection Processor is triggered by false messages varies considerably for a fixed signal-to-noise ratio. This problem was first considered by Lacoss (1972) during a research visit to NORSAR (11). The work is continuing at NORSAR aiming at a floating event acceptance threshold, varying with the false alarm probability. Preliminary results indicate that such a change would increase the number of reported events by around 5 per cent.

1.2 The potential gain in signal-to-noise ratio using seismic arrays

The operational principle of an array is based on the assumption that the signals are identical across the array and the noise is approximately independent and uncorrelated from one sensor to another. In this case, simple delay and sum processing gives an optimum gain of $\sqrt{N}$ where $N$ is the number of sensors. Although
the above noise model is usually valid, the \( \sqrt{N} \) gain in signal-to-noise ratio (SNR) is never achieved, as the individual sensor P-signals are corrupted by small and large-scale inhomogeneities in the earth. For example, the signal amplitude distribution across NORSAR may be approximated by a lognormal probability density distribution. On the other hand, more sophisticated processing methods for maximizing the gain in SNR using more generalized signal models have been developed by Christoffersson and Jansson (7) and recently applied to NORSAR recorded events. The relative improvements in SNR in comparison to conventional array beamforming is very promising, as shown in table 1 below, for some randomly selected events in Central Asia.

<table>
<thead>
<tr>
<th>No.</th>
<th>Region</th>
<th>SNR</th>
<th>RMS</th>
<th>AMP</th>
<th>R and A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W. Russia</td>
<td>2.46</td>
<td>0.15</td>
<td>6.02</td>
<td>6.60</td>
</tr>
<tr>
<td>2</td>
<td>W. Russia</td>
<td>3.00</td>
<td>0.16</td>
<td>4.84</td>
<td>5.14</td>
</tr>
<tr>
<td>3</td>
<td>Uzbek Soviet Socialist Republic</td>
<td>2.73</td>
<td>0.09</td>
<td>2.04</td>
<td>2.74</td>
</tr>
<tr>
<td>4</td>
<td>C. Kazakh</td>
<td>3.21</td>
<td>0.39</td>
<td>0.41</td>
<td>2.52</td>
</tr>
<tr>
<td>5</td>
<td>Sinkiang</td>
<td>3.04</td>
<td>0.12</td>
<td>5.20</td>
<td>5.11</td>
</tr>
<tr>
<td>6</td>
<td>Czechoslovakia</td>
<td>1.89</td>
<td>0.78</td>
<td>7.65</td>
<td>7.20</td>
</tr>
<tr>
<td>7</td>
<td>Ural Mountains</td>
<td>3.21</td>
<td>0.16</td>
<td>1.85</td>
<td>2.21</td>
</tr>
<tr>
<td>8</td>
<td>W. Kazakh</td>
<td>1.51</td>
<td>-0.09</td>
<td>3.48</td>
<td>5.91</td>
</tr>
</tbody>
</table>

Relative processing gains for "difficult" events in Eurasia. The SNR column gives the signal-to-noise ratio measured during standard event detection processing. The columns RMS, AMP, and R and A give relative gain in SNR in db by using noise level, signal amplitude and noise and amplitude weighting functions.

This new processing scheme is currently under implementation at NORSAR and is considered a very powerful tool in discriminating between false alarms and small seismic signals.

For implementation in the real-time event-detection processor, the method can be simplified taking into consideration that the P-signals recorded by the array are not changing much within the individual seismic regions. This so-called master event technique proved very efficient for small seismic events in the Japan region (see table 2).
Table 2

<table>
<thead>
<tr>
<th>EVENT No.</th>
<th>RMS</th>
<th>AMP</th>
<th>R and A</th>
<th>MASTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.62</td>
<td>1.28</td>
<td>1.10</td>
<td>0.98</td>
</tr>
<tr>
<td>2</td>
<td>0.76</td>
<td>2.63</td>
<td>2.84</td>
<td>0.65</td>
</tr>
<tr>
<td>3</td>
<td>0.23</td>
<td>3.03</td>
<td>2.98</td>
<td>3.07</td>
</tr>
<tr>
<td>4</td>
<td>0.25</td>
<td>3.44</td>
<td>3.24</td>
<td>2.29</td>
</tr>
<tr>
<td>5</td>
<td>0.30</td>
<td>3.23</td>
<td>3.70</td>
<td>2.86</td>
</tr>
<tr>
<td>6</td>
<td>0.25</td>
<td>3.23</td>
<td>4.13</td>
<td>0.80</td>
</tr>
<tr>
<td>7</td>
<td>0.01</td>
<td>2.29</td>
<td>2.36</td>
<td>2.34</td>
</tr>
<tr>
<td>8</td>
<td>0.16</td>
<td>1.88</td>
<td>1.98</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Relative processing gains in db for eight different earthquakes in Japan. For an explanation of columns RMS, AMP, and R and A, see the caption for table 1. The MASTER column gives the score based on standardized amplitude weights. The latter were taken as the average of amplitude weights for 10 good (the so-called master) events in the Japan region.

An alternative processing method to that of Christoffersson and Jansson (7) would be to take advantage of the skewness in the amplitude distribution across the array by masking subarrays having relatively small P-wave amplitude for a specific region. The gain in signal-to-noise ratio as compared to current beamforming would then still be significant.

1.3 Data processing in view of signal complexity across the array

In general, the P-waves generated by earthquakes or underground nuclear explosions in the Eurasian continent are very complex and partially incoherent across the array. This means that, for many parts of this region, conventional beamforming is not quite a satisfactory procedure for detecting weak events. Henceforth, the method of incoherent beamforming (see figure 1) has been implemented at NORSAR as a supplement to conventional beamforming.

Characteristically for incoherent or envelope beamforming is that this method does not give noise suppression, but instead reduces the noise variability. The main advantages of the incoherent beamforming are (a) the relative low frequency envelope signals are nearly identical across the array, (b) the number of incoherent beams required for adequate coverage of all seismic regions is relatively few, and (c) noise suppression using high-frequency bandpass filters is feasible in incoherent beamforming as this operation may be performed prior to the calculations of the signal envelopes. For further details, we refer to a paper by Ringdal et al. (12), from which a comparison between the operational event detectability performance between conventional and incoherent beamforming, presented in table 3, is taken.
The signal envelopes represent STA (Short-Term Average) values, defined as the average of rectified signal amplitudes over a 1.5 sec. sliding integration window. (From Ringdal et al., 1972 (12).)
Table 3

<table>
<thead>
<tr>
<th>ZONE</th>
<th>EVENTS</th>
<th>COH. BF.</th>
<th>INC. BF.</th>
<th>COH. and INC. Total</th>
<th>COH. BF. Total</th>
<th>INC. BF. Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td></td>
<td>Total</td>
<td>Only</td>
<td>Only</td>
<td>Per cent</td>
<td>Per cent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>number</td>
<td>number</td>
<td>number</td>
<td>number</td>
<td>number</td>
</tr>
<tr>
<td>1</td>
<td>Greece/Turkey</td>
<td>117</td>
<td>5</td>
<td>45</td>
<td>67</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>USSR/Central Asia</td>
<td>194</td>
<td>28</td>
<td>41</td>
<td>125</td>
<td>153</td>
</tr>
<tr>
<td>3</td>
<td>Japan/Kam./Aleu.</td>
<td>168</td>
<td>40</td>
<td>7</td>
<td>121</td>
<td>161</td>
</tr>
<tr>
<td>4</td>
<td>USA/Central America</td>
<td>64</td>
<td>31</td>
<td>1</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>Global I (All events)</td>
<td>1,038</td>
<td>242</td>
<td>135</td>
<td>663</td>
<td>905</td>
</tr>
<tr>
<td>6</td>
<td>Global II (High-quality events)</td>
<td>546</td>
<td>24</td>
<td>25</td>
<td>497</td>
<td>521</td>
</tr>
</tbody>
</table>

Events reported in the NORSAR Seismic Bulletin, 16 September-15 November 1972. The table gives the total number and per cent of events detected in different regions by the coherent (COH) and incoherent (INC) beamforming (BF), as well as the number of events detected only by one of these detectors. (From Ringdal et al., 1972 (12).)

As is well known, P-wave spectra vary as a function of seismic regions, while noise spectra exhibit seasonal and diurnal variations, implying that the maximum of the signal-to-noise ratio parameter is frequency dependent. This effect has been compensated for by making the frequency filters in the NORSAR data analysis system regionally dependent.

1.4 Multi-array processing for event detection

A common approach to multi-array processing is the so-called voting technique, that is, an event detection at one array or station is verified by corresponding detections at other stations or arrays, imposing proper time and geographic space constraints. In this way, the capability of each station is retained, and it is furthermore possible to be less strict regarding the signal-to-noise ratio required for detection since a signal seen at several stations could be determined to be of seismic origin even if the signal at each individual station is too weak to produce any definite conclusion. However, the gain by the above method may be limited, as the number of false alarms increases exponentially with decreasing thresholds.

On the other hand, real-time incoherent beamforming using a global network of arrays and ordinary seismic stations is a viable alternative (Husebye et al., 1972) (10). Using that method, they found that the maximum signal-to-noise ratio relative to the most sensitive station may amount to 2-8 db, and not more than
8-16 stations are needed for covering a specific region. Also in this type of event-detection procedure, advantage is taken of the skewness in the P-wave amplitude distribution. The essential point here is that very small events in a specific region are reported only by a small number of stations which have an exceptionally good event detectability for that particular region. For another seismic area, another set of stations would exhibit the best event detectability. For example, NORSAR reports relatively many more small earthquakes in Asia than in North America, so that the array's contribution to improve event detectability in the latter region is marginal.

Finally, it should be remarked that experiences from the NORSAR array have shown that no one of the three methods - conventional beamforming, incoherent beamforming between subarrays and voting between subarrays - is consistently better than the others. These methods may simply be considered to supplement each other.

1.5 Evaluation of routine NORSAR event detectability

Two approaches have been used for mapping the NORSAR event detection capability. In the first case, the standard procedure of estimating the 90 per cent cumulative detectability as a function of NORSAR $m'_b$ magnitude was used (see figure 2). The cumulative 90 per cent threshold is the magnitude at which 90 per cent of all larger-magnitude events are reported. This threshold is usually around 0.2 magnitude units smaller than the incremental value, which is sometimes also used. However, the cumulative threshold can be estimated with much better precision, and has therefore been used here.

Using that technique, observed values for detectability have been published (Bungum (2)) using data from February to June 1972, and is also presented in table 4. A more extensive analysis of this sort, using one full year of data, will be published (Bungum and Husebye (3)).

A more unconventional procedure considered was to calculate the cumulative operational noise level probability distribution over certain time intervals, and then converting this parameter to equivalent $m'_b$ magnitude units. The essentials of this procedure are shown in figure 3. For further details, we refer to a paper by Berteussen and Husebye (1). The two methods compare favourably to each other, as shown in table 4.

The NORSAR array became operational in March 1971, and its event detection capability has improved considerably since that time. The principal factors here are much improved time correction files required for the beamforming process, more flexible bandpass filter setting, implementation of so-called incoherent event detector and the experience gained by operating the sophisticated processing system of the NORSAR array. Presently, the array reports an average of approximately 20 seismic events per day.
Figure 2

Interval and cumulative frequency-magnitude distribution for data from February-June 1972, epicentral range 30° - 90°

NORSAR MB

Straight line is a least squares fit through data within bars. (From Bungum, 1972 (2).)
Table 4
Observed and predicted $m_b$ detectability levels for the NORSAR array

<table>
<thead>
<tr>
<th>ZONE</th>
<th>ZONE LIMITS</th>
<th>OBSERVED $m_b$ LEVELS</th>
<th>PREDICTED $m_b$ LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Name</td>
<td>Azi(deg) Dist(deg)</td>
<td>Number of events per</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 90 50 90</td>
</tr>
<tr>
<td>1</td>
<td>P-zone</td>
<td>0-360 30-90</td>
<td>1 555 3.57 4.03</td>
</tr>
<tr>
<td>2</td>
<td>Atlantic</td>
<td>180-260 30-90</td>
<td>88 3.64 4.26</td>
</tr>
<tr>
<td>3</td>
<td>N. America</td>
<td>260-340 40-90</td>
<td>114 3.72 4.06</td>
</tr>
<tr>
<td>4</td>
<td>Aleutian Is.</td>
<td>340-15 30-00</td>
<td>131 3.40 3.90</td>
</tr>
<tr>
<td>5</td>
<td>Japan</td>
<td>15-70 50-90</td>
<td>738 3.66 4.07</td>
</tr>
<tr>
<td>6</td>
<td>C. Asia</td>
<td>40-110 30-90</td>
<td>211 3.21 3.60</td>
</tr>
<tr>
<td>7</td>
<td>Iran (1)</td>
<td>110-180 30-90</td>
<td>262 3.45 3.80</td>
</tr>
<tr>
<td>8</td>
<td>Iran (2)</td>
<td>110-130 35-50</td>
<td>188 3.42 3.78</td>
</tr>
</tbody>
</table>

The observational data (see Bungum (2)) covers the interval from February to June 1972. (From Berteussen and Husebye (1).)

The potential improvement in event detectability due to improved data processing schemes like the previously discussed amplitude weighting and the more flexible threshold setting are easily evaluated when the relative gain is expressed in db units. The point is that 0.1 $m_b$ magnitude unit corresponds to 2 db so the 90 per cent cumulative event detectability improvement can be directly obtained from figure 3. Alternatively, we may use the formula

$$\log N = a-b m_b$$

where $N =$ number of reported events with magnitude greater than $m_b$ in a certain time interval, and $a$ and $b$ are regression coefficient (see also figure 2).

The improved event reporting capability $dN$ can then be expressed as:

$$dN = N(10^{-dm}-1)$$

where $dm$ is gain in SNR expressed in magnitude units.

Section 2. Seismic verification research

So far, our main research efforts have been aimed at improving the event detectability and location capability of the NORSAR array. Some investigations on the array's capability to discriminate between earthquakes and explosions have already been undertaken, although at the present stage only conventional classification criteria have been used in the analysis of relevant NORSAR data.
Figure 3

The left-hand curve gives the observed cumulative noise distribution measured in the interval from February to June 1972. The centre curve is obtained by adding the operational threshold parameter of 11.5 db to the first curve. The right-hand curve is the sum of the centre curve and the observed cumulative loss distribution for teleseismic events. The dotted lines show the 90 per cent confidence intervals of the left-hand and right-hand curves. (From Berteussen and Husebye (1).)
2.1 Event discrimination using the $m_b : M_s$ criterion

The main problem with the application of $m_b : M_s$ criterion is to be able to detect the surface waves from small explosions and earthquakes. Three major signal enhancement techniques have been used in analysis of NORSAR surface-wave data with good results, namely:

(a) Bandpass filtering centred at around 20 seconds, reducing the 6-second microseismic energy, which sometimes can be very strong in the winter;

(b) Beamforming, which works well if the noise is separated in azimuth from the signals (the signal similarity is always high);

(c) Matched filtering, which is a master event technique that takes advantage of the time invariance of recorded Rayleigh waves.

Figure 4 shows the results from an $m_b : M_s$ study where those techniques have been applied for signal enhancement. The lowest $M_s$ reported is 2.5; however, at other times $M_s$ 3.5 may not be detected due to variations in the background noise. Preliminary results from an $m_b : M_s$ study at NORSAR were published (1972) by Filson and Bungum (8).

2.2 Event discrimination using short-period $P$-waves

The $m_b : M_s$ discrimination criterion works reasonably well for larger seismic events. However, the difficulty of detecting surface waves in the low-magnitude range necessitates investigations of event classification capabilities based solely on $P$-waves. Modified versions of the so-called complexity and third moment of frequency criteria have been tested on NORSAR recorded events - earthquakes located in Eurasia and North America. In the latter region, event discrimination using $P$-waves only is relatively poor, and also the array's event detection capability is not specially good. On the other hand, preliminary results indicate that fairly good discrimination between earthquakes and presumed underground explosions is achievable for Eurasia. This statement is restricted to event distances larger than around 3,000 kilometres from NORSAR, as the modified complexity criterion does not give satisfactory results for shorter distances.

2.3 Rayleigh-wave interference and multipath effects

In addition to the seismic noise, there is for long-period waves an important limiting factor for detectability in the fact that waves from two events very often interfere with each other, maybe as much as 20 per cent of the time. The long-period coda from a large event may last for hours, and another complicating factor is that the energy is often scattered in azimuth through reflections and refractions at continental margins. A study is now in progress where the energy distribution in the coda for a number of carefully selected events is studied at 20- and 40-second periods. The advantage of working at 40-second periods is that the multipathing there is much less severe and that the coda fall off more rapidly. On the other hand, some events may have energy only around 20-second periods. The results for NORSAR are comparable to those
Figure 4

Body-wave magnitude $m_b$ versus surface-wave magnitude $M_s$ for events located by NORSAR in Central Asia during 1971 and 1972.

Open circles indicate presumed nuclear explosions.
previously obtained for LASA by Capon (6), although it seems that NORSAR data gives less variation in the way the coda around 40-second wave periods fall off with time.

2.4 Bias analysis of NORSAR reported $m_b$ magnitudes

The $m_b$ magnitude parameter, measured on records of short-period P-waves, is a convenient and widely used tool for the ranking of earthquakes. More recently, this parameter has become of critical importance in evaluating event detection and discrimination capabilities of various kinds of seismological stations and networks. The problem of a possible bias in the NORSAR estimation procedure of $m_b$ magnitudes has been investigated by Husebye et al. (1973) (9), and the main results are as shown in figure 5.

The NORSAR reported event magnitude is unbiased as the P-signal loss occurring during processing is compensated by the skewness in amplitude distribution. On the other hand, NORSAR reports $m_b$ values consistently lower than those of NOAA (National Oceanic and Atmospheric Administration) for event magnitudes larger than 4.0. Most important, for (very) small events, $m_b \Delta 4.0$, NORSAR reports too large $m_b$ values as compared to NOAA (see figure 4). More extensive data on the NORSAR-NOAA $m_b$ magnitude relationship will be published in a forthcoming paper by Bungum and Hüsebye (1973) (3).
Figure 5
NOAA/NORSAR body-wave magnitude difference versus NOAA magnitude
for events with epicentral range 30° - 90° from NORSAR

The data is averaged over bands of 0.3 magnitude units, the number at each point gives number of magnitude pairs used in average and the upper and lower bounds are standard deviations.
REFERENCES


20. FINLAND

Letter dated 9 August 1973 from the Acting Permanent Representative of Finland to the Special Representative of the Secretary-General to the Conference of the Committee on Disarmament (CCD/412)

[Original: English]/14 August 1973/

Upon instructions from my Government, I have the honour to enclose a working paper by the Government of Finland to the Conference of the Committee on Disarmament with the request that you would take appropriate steps to have it distributed in the Conference of the Committee on Disarmament.

(Signed) Seppo KAUPPILA
Acting Permanent Representative of Finland
Working paper by the Government of Finland on the progress of the Finnish project for the creation on a national basis of a chemical weapons control capacity for possible future international use

1. In the working paper presented by the Government of Finland to the Conference of the Committee on Disarmament a year ago (CCD/381), it was stated that:

"There is a need for substantive preparatory work in the field of promoting scientific knowledge and co-operation in the study of technical problems connected with the verification and control of chemical weapons within the framework of a chemical weapons treaty now under consideration in the Conference of the Committee on Disarmament."

The Finnish project was intended to concentrate on the creation of a national chemical weapons control capacity for possible future international use and would focus, in the first instance, on the group of nerve agents. The goals of the Finnish project were further described in a statement by the representative of Finland in the First Committee of the General Assembly of the United Nations on 7 November 1972, as follows:

"In a way the Finnish project looks beyond the present toward a situation when a chemical weapons treaty may have become a reality. In order to be useful in alternative situations which a future treaty may entail, it has been conceived as a multipurpose project both substantially and functionally. Substantially the planned control capacity would be useful in three different verification activities: verification of the destruction of stocks, of non-production of chemical weapons and of alleged use. Functionally the capacity could be of service whatever the ultimate solution of the verification problem might be; it would obviously be useful for national verification in Finland or any combination of national inspection with international elements. It could also be of potential use in connexion with an investigation ordered by the Security Council subsequent to a complaint. Finally, it seems to respond to a concern which has been voiced in the Conference of the Committee on Disarmament by a number of developing countries because of their difficulties in shouldering the tasks of verifications by their available national means only." 50/

2. The Finnish project has proceeded as planned. Concrete research work was initiated in the spring of 1973 when budgetary funds became available. The project is under the direction of the Foreign Ministry and supervised by its Advisory Committee on Disarmament. Its purpose is to train scientific experts and to develop verification and control methods for chemical agents. At its initial stages, the work focuses on chemical problems and enzymatic methods for the detection of the effects of nerve agents. The work is divided among six research teams located in the following laboratories of Finnish universities and the Defence Forces.


50/ A/C.1/PV.1885, pp. 44-45.
The research teams have at their disposal very modern scientific instrumentation, including gas chromatograph-mass spectrometry units with computerized data processing, IR and NMR spectrometers etc.

3. The initial research programmes focus on the following aspects of organophosphorus nerve agents:

(a) Their synthesis, including precursors of binary systems;

(b) Their analysis, primarily by gas chromatography and thin-layer chromatography;

(c) Their detection by the anticholine esterase method and by specific indicator reactions;

(d) Their decomposition reactions and the persistence in nature of their decomposition products.

Identification of unknown compounds is most effective when a large collection of reference samples is available. In addition to all possible nerve agents of military interest and related organophosphates with peaceful uses, like insecticides, identification of their precursors, intermediates and decomposition products is also relevant. This requires a considerable amount of synthetic work, part of which has to be carried out in a special laboratory with appropriate safety arrangements. Because the scope and nature of a possible chemical weapons convention are as yet undetermined, the goals of the project are defined with a certain flexibility. Initially, however, the emphasis is on analytical methodology.

4. It is hoped that one of the results of the project will be an analytical handbook, which could be useful in the verification activity of national control systems, of possible international groups of experts or of other international disarmament control and monitoring organs ("IDO", "UN-DISCO"), as proposed, for example, by the representative of Sweden (CCD/FV.610, p. 13) or in the working paper of the Netherlands submitted to the Conference of the Committee on Disarmament on 31 July 1973 (CCD/410).

5. The socialist countries have devoted a working paper (CCD/403) to national verification activities. To carry out such activities requires, of course, specialized scientific expertise that may not be readily available to all nations. Reliable chemical data in handbook form could therefore be useful for national as well as international control and verification activity. It is hoped that the Finnish Project can provide a contribution, albeit a modest one, in this field.

The Finnish Government will keep the Conference of the Committee on Disarmament informed about the future progress of this project.
21. JAPAN

Working paper on the main points of an international agreement on
the prohibition of the development, production and stockpiling of
chemical weapons and their destruction (CCD/413)

[Original: English]
[21 August 1973]

In his statements on 22 March (CCD/PV.594) and 26 June 1973 (CCD/PV.607), the
Japanese representative, Ambassador Nisibori, suggested that a gradual approach be
adopted in a practical as well as realistic manner, in order to facilitate an
early settlement of the question of banning chemical weapons.

Using this as a basis and with a view to facilitating the settlement of this
question in a concrete manner, the Japanese delegation presents the present
working paper, which includes suggestions on an international agreement embodying
a treaty and its supplementary document.

The working paper contains the following main headings: general items, scope
of prohibition and verification.

I. General items

1. The international agreement on banning chemical weapons would incorporate
(a) a treaty which prescribes a comprehensive ban and (b) a supplementary document
defining the scope of the foregoing treaty. The supplementary document would be
regarded as an inseparable part of the treaty. The procedures allowing for
amendments to the supplementary document would be simplified ones and would be
included in the treaty.

2. While the matters which should be prohibited in the international agreements
cover (a) activities (development, production, stockpiling, transfer etc.),
(b) chemical agents and (c) weapons, equipment and means of delivery, Japan
considers it appropriate to start temporarily with a partial ban on (a) activities
and (b) chemical agents.

3. In drafting the international agreement, the following formula may be
considered:

The treaty would first prescribe in a comprehensive manner the matters
 enumerated in (a), (b) and (c) above to be prohibited, and then the
supplementary document and a provision of the treaty would prescribe the matters
to be excluded temporarily from the comprehensive ban.

In prescribing the exclusions, a choice between the two following formulae is
suggested:

(1) The supplementary document would prescribe a part of the matters
(enumerated in (a) and (b) above) to be excluded and a provision of the treaty would prescribe that the foregoing matters be excluded from a comprehensive ban;

(2) The supplementary document would prescribe a part of the matters (enumerated in (a) and (b) above), and a provision of the treaty would prescribe that matters other than those mentioned in the supplementary document be excluded from a comprehensive ban.

4. In adapting either of the foregoing formulae of the treaty prescribing a comprehensive ban (including (1) and (2) above), Japan considers it appropriate to place a ban in the treaty on:

(a) The developing, producing, stockpiling or otherwise acquiring or retaining of; and

(b) The transfer and assistance, encouragement, or inducement in the manufacture or acquisition of;

chemical agents and weapons, equipment or means of delivery designed to use such agents.

5. On matters which have been excluded temporarily from a comprehensive ban, the treaty should include a provision by which States parties to the treaty undertake to continue negotiations in good faith in order to agree at the earliest date on concrete measures for realizing a comprehensive ban.

6. The treaty would contain a provision that each State party to the treaty undertakes to conduct national verification probes which by nature are autonomous, and also another provision under which international verification would be conducted for the purpose of ensuring the fulfilment of the obligation assumed under the treaty. Details pertaining to national and international means of verification would be provided in the supplementary document.

7. Relations between the Geneva Protocol and the international agreement on banning chemical weapons, consultation and co-operation among the States parties, and such procedural matters as entry into force and duration of the treaty would be drafted in conformity with the corresponding provisions of the bacteriological weapons treaty.

II. Scope of prohibition

1. While general purpose criteria (e.g. types and quantities that have no justification for protective or peaceful purposes) would be adopted in a comprehensive ban on the agents, the agents which for a partial ban should be prohibited immediately, as mentioned in section I, paragraph 2, would be prescribed in the supplementary document under objective criteria (for example, toxic criteria, general structural formulae, listing etc.).

2. General purpose criteria (for example, for hostile purposes or in armed conflict) would be adopted in a comprehensive ban on the weapons, equipment and means of delivery, as mentioned in section I, paragraph 2. Japan considers developing, producing, transferring and acquiring as the activities which should be prohibited immediately.
3. The supplementary document would contain an additional provision prescribing that the time and formula for the destruction or diversion for peaceful purposes of chemical agents, weapons, equipment, means of delivery etc., as mentioned in paragraphs 1 and 2 above, are to be settled at the time of the agreement on concrete measures for banning their stockpiling.

III. Verification

1. National verification

National verification to be conducted by each State party to the treaty would be primarily autonomous, its purpose being to ensure the fulfilment of the treaty. Study should be made as to the inclusion of an obligatory provision in the treaty which would oblige each State party to co-operate when necessary with the international verification organization mentioned in section 2 below, including reporting on a regular basis to the organization on matters deemed necessary for the purpose of ensuring the fulfilment of the treaty.

2. International verification

International verification would be conducted by an international verification organization. Activities of the organization would include constant and objective surveillance and inquiry as deemed necessary.

If an inquiry is conducted by the international verification organization, it would be desirable for the treaty to contain a provision which obliges the organization to report the results of the inspection to an appropriate United Nations organ, in order to define relations between the organization and the United Nations.

The supplementary document would have an additional provision regarding the composition, activities etc. of the international verification organization.

3. Request for explanation

Both the international verification organization and States parties to the treaty would be permitted to request an explanation in the case of suspected breach of obligations deriving from the treaty. It might be effective for the treaty to contain the following provisions on the procedures for this purpose:

(1) The international verification organization or any State party to the treaty which suspects that any other State party is acting in breach of obligations deriving from the treaty may request an explanation from the other party in question;

(2) A State party which has not received a satisfactory explanation from the other State party in question through the foregoing procedure (sect. 3, para. (1)) may request an inquiry by the international verification organization.

-201-
4. **Inspection**

It would be useful for the treaty to contain provisions on the following procedures on inspection to be conducted by the international verification organization:

(1) A State party which has been required to provide an explanation in accordance with section 3, paragraph (1) above, may at any time invite the international verification organization to conduct on-site inspection;

(2) The international verification organization may notify a State party of its planned inspection in case (a) the organization finds that the State party has not provided a satisfactory explanation and that it is acting in breach of the obligations deriving from the treaty, or (b) a request for inspection is filed by any other State party;

(3) Any State party which is notified by the international verification organization of its planned inspection would have to give strong reasons for not complying with the notification.
The problem

1. The purpose of the present paper is to address the question of defining as simply and unambiguously as possible the substances that might be banned or controlled as chemical weapon agents if a comprehensive agreement on chemical weapons could be negotiated.

2. As the effects of chemical substances on living organisms are both varied and complex, it has proved difficult to formulate simple definitions to separate those chemicals that are relatively harmless from those that have military utility and which are also in production for civil purposes.

3. A widely expressed view in the Conference of the Committee on Disarmament has been that a treaty could set out the scope of a comprehensive ban by way of a general description of the chemical agents to be affected by a general-purpose criterion, while more detailed technical provisions could be elaborated in an annex to the treaty which could be subject to periodic review and revision by an international body established for that purpose by the treaty. There has also been a view that to the extent possible the scope of a treaty should encompass the chemical agents found in civil use which have been or could be put to military use.

4. This paper examines the basis on which a general-purpose criterion in a comprehensive treaty could be supplemented by a more detailed technical scheme of definition of chemical warfare agents based on levels of toxicity of chemicals. It also examines how such a scheme of definition could be used, together with other definitions, to assist in establishing the scope of prohibition under a treaty.

5. It is useful at this point to draw attention to the meaning of some of the terms used in this paper:

   (a) Toxic means poisonous in the sense of causing physiological injury to a human; this effect includes blistering, blindness and death;

   (b) Supertoxic means highly poisonous, that is, only very small quantities are needed to produce physiological harm; in practice, for the modern nerve agents, this means death;

   (c) Binary agents or precursors are agents employed in weapons in which the components necessary to produce a supertoxic agent are kept separated until mixed during the process of delivery. The main advantage of such a weapon is the ease of handling.
Approaches to defining chemical weapon agents

6. From a number of working papers presented to the Conference of the Committee on Disarmament, it is apparent that three general approaches to defining chemical weapon agents can be employed:

   (a) A definition based on purpose or intent;

   (b) A strict technical definition of chemicals based on generalized formulae, supplemented where necessary by the specific identification of chemicals; and

   (c) A definition based on chemical agent effects, as in the Geneva Protocol.

7. A definition based on purpose or intent. This approach would be exemplified by a general criterion derived from the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, requiring the prohibition of "agents ... of types and in quantities that have no justification for ... peaceful purposes" and "weapons, equipment or means of delivery designed to use such agents ... for hostile purposes or in armed conflict".

8. A general prohibition based on purpose or intended use, given the difficulty of objectively identifying intent, might not take sufficient account of technical considerations to allow a meaningful chemical weapon prohibition. The filling of munitions with toxic chemicals and the production or stockpiling of single-purpose agents are the only self-evident measures. However, it would be possible to use toxic chemical weapons in war without employing either single-purpose agents or special munitions. Hence the need has been seen to supplement a general-purpose criterion with technical definitions.

9. A definition of chemical substances based on generalized formulae. This approach is based on the idea that it may be possible to derive a generalized formula or series of such formulae which would encompass all agents, present and future, that could have military utility. To be valid, however, this approach would require a direct correlation between formula and desired military effectiveness. Unfortunately, it has not proved generally possible to determine the lethality of a chemical from an examination of its molecular structure or its formula, nor to predict lethality from the formula of an untested compound.

10. While this correlation cannot be established generally, there has been some success in relating the formulae of organophosphorus compounds to toxicity /CCD/320 (Netherlands), 51/ CCD/365 (United States), 52/ CCD/374 (Japan) 52/ / and it may be possible to extend this concept to the mustards and arsines. On the other hand, for carbamates and some of the older dual-purpose agents, even a limited general formula approach has not proved to be practical and it becomes necessary to list specific compounds.


52/ Ibid., Supplement for 1972, document DC/235, annex B.
11. A definition based on chemical agent effects. This approach is similar to that in the Geneva Protocol, which prohibits "the use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices".

12. Agents having lethal effects or producing serious and permanent injury can be described by toxicity. Discussion of toxicity and the methods of its measurement have been features of a number of presentations to the Conference of the Committee on Disarmament /e.g., Canada (CCD/387), 52/ Japan (CCD/301, 53/ 374 52/) and Sweden (CCD/372) 52/. There has been no discussion of other agent effects.

13. A scheme of definitions based on toxicity has the strength of focusing on the effects which are of military importance: death or permanent injury. By establishing lines of demarcation or thresholds, based on the dosages required to produce such effects, it is possible to define chemicals as agents of war and, supplemented by agreement on whether a chemical agent has civil uses, to establish for different chemicals the scope of activities which should be prohibited.

14. A general-purpose criterion may be essential to a treaty to describe its broad intent and to encompass certain chemical weapon agents and weapons; of the technical means of supplementing such a general-purpose definition, the third of the approaches to definition holds the most promise.

Toxicity thresholds

15. The question arises whether, by considering a range of toxicity, a toxicity threshold can be established above which compounds can be considered as potential weapons and below which, for all practical purposes, no such potential exists.

16. A number of papers of the Conference of the Committee on Disarmament have discussed the concept of a threshold by considering the determination of a line of demarcation (CCD/372) or a target point (CCD/374) to separate the single-purpose supertoxic agents from all other chemicals of lower toxicity, including some which have military application. This threshold of effective median dosage is used as the upper or first threshold in the present paper and could be used to separate modern single-purpose "nerve" agents from those of lower yet significant lethality.

17. To assist in the problem of defining those chemical agents of lower toxicity but potential military usefulness from the rest, it is proposed to introduce the concept of a second threshold to separate militarily useful agents from those chemicals that have no practical potential as chemical weapon agents. This lower threshold would serve to define the scale of toxicity so that any militarily useful chemical would be above this boundary, while those below would be classed as non-military.

18. For the purposes of the present paper, an upper threshold is set by naming tabun, the least toxic of the single-purpose supertoxic agents, as a boundary agent. Other supertoxic agents would fall above tabun. Mustard would be just below this threshold. Chlorine, which is not a highly lethal agent, could be used to set the lower threshold or level of the least military significant lethal agent.

19. This classification of toxic chemical agents is shown in table 1 below.

20. While no numerical values of these thresholds for toxic agents are included in the table, the following values are suggested:

- Upper threshold: \( \text{Lct}_{50} = 500 \text{ mg.min/m}^3 \)
- Lower threshold: \( \text{Lct}_{50} = 20,000 \text{ mg.min/m}^3 \)

(\( \text{Lct}_{50} = \) Dosage vapour concentration multiplied by time of exposure lethal to 50 per cent of exposed personnel. (The toxicity units chosen depend on inhalation. Equivalent values for dosages associated with other methods of exposure, for example, through the skin or the eyes, could be derived. Uncertainties in the dosage value of a particular agent are within the range defined by the threshold valued.))

21. The upper threshold is suggested because of the major difference of toxicity between tabun and mustard, and should be the subject of both international discussion and agreement. This value has no significance in the definition of a chemical as an agent of war. It is relevant, however, to the scope of activities which might be prohibited, for once one drops below this toxicity level, one begins to encounter toxic chemicals in industrial use.

22. The lower value was also chosen somewhat arbitrarily. Chlorine, although used in the First World War, is not now considered as an effective agent and has been relegated by some countries to training purposes. It might be regarded as the least toxic agent to have military utility, at least against an unprotected force.

23. From this, it now seems possible to suggest a general definition of toxic chemical substances that might be agents of war subject to control and/or prohibition: a chemical compound or element can be considered as an agent of war if its toxicity has a median lethal dosage less than 20,000 mg.min/\( m^3 \) or a practical equivalent of this dosage.

Use of agent definitions in establishing scope of prohibition

24. Having now suggested a system for identifying chemical substances as being potential agents of war, it remains to consider how these definitions might be applied in determining the scope of prohibition of a comprehensive chemical weapons ban.

25. Thresholds have been suggested which separate those chemical substances which have military potential based on their lethality, from those that do not have such a potential. (Some of the chemical substances thus defined as being potential agents of war also have recognized peaceful uses.)

26. A threshold of toxicity has been suggested which defines the supertoxic compounds for which there are no recognized peaceful uses (other than for small quantities required for defensive research and medical purposes). From this, it is possible to suggest that the development, production, and stockpiling of these chemicals could be prohibited if a chemical weapons prohibition could be negotiated.
27. Of those toxic chemical substances identified by the lower threshold as being potential agents of war, but which fall below the upper threshold, some have recognized civil uses, that is, the "dual purpose" toxic agents having peaceful industrial uses. It would, therefore, not be possible to ban the development, production and stockpiling of these chemicals solely on the basis of their place on the scale of toxicity. It is suggested that an international committee of experts could identify those chemicals having such civil uses for which development, production and stockpiling could be permitted. However, the filling of military ordnance with toxic dual-purpose industrial chemicals could be prohibited. The development, production and stockpiling of other chemicals above the lower threshold and not identified as having recognized civil uses could be prohibited. The toxic chemicals in this latter subclass could be identified by specific formula in some cases and possibly by family of formulae for others (both the mustards and arsines may be accommodated by the "family approach").

28. Binary weapons are designed to create a supertoxic compound only on discharge; it is likely that in any binary system at least one of the components would have a toxicity falling above the lower threshold. If this component were identified as having a civil purpose, it could be treated in the same way as the other dual-purpose agents; that is, its production and stockpiling for peaceful purposes might be permitted, but the filling of munitions with such binary weapons components could be prohibited.

29. For illustrative purposes the application of the types of definition to the scope of prohibition is shown in condensed form in table 2.

---

The formula approach is considered to be useful in the case of older single-purpose toxic agents because (a) the exhaustive surveys that have been undertaken since the First World War have not produced compounds significantly better than those already known, and (b) there may be no incentive to find new chemicals in this range of lethality when the supertoxics exist, on the one hand, and where there are dual-purpose agents available on the other hand. If in any event such chemicals were discovered, they could be added to any list of specifically proscribed compounds.
**Table 1**

Classification of some chemical compounds and elements based on toxicity including subgroupings based on purpose

<table>
<thead>
<tr>
<th>Lethal agents</th>
<th>Lc₅₀[^c]/ mg.min/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>VX</td>
<td>10-50</td>
</tr>
<tr>
<td>Sarin</td>
<td>100</td>
</tr>
<tr>
<td>Soman</td>
<td>50-100</td>
</tr>
<tr>
<td>Tabun</td>
<td>400</td>
</tr>
</tbody>
</table>

**UPPER THRESHOLD**

- Mustard 1500
- Lewisite 1500

**Toxic**

- Arsine 5000
- 3200 Phosgene Toxic
- 5000 HCN

**SINGLE PURPOSE**

- 11000 Cyanogen Chloride

**DUAL PURPOSE**

- 19000 Chlorine

**LOWER THRESHOLD**

All other chemicals that have no significant military value

[^c]: Dosage vapour concentration multiplied by time of exposure lethal to 50 per cent of exposed personnel.

[^b]: Chemicals having both military and civil uses.
Table 2
Application of types of definitions to the scope of prohibition: Illustrative only

<table>
<thead>
<tr>
<th></th>
<th>Super-toxic</th>
<th>Single-purpose toxic</th>
<th>Dual-purpose toxic</th>
<th>Binaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development production</td>
<td>Banned by</td>
<td>Banned by toxicity</td>
<td>Allowed (determined by agreement as being required for civil use and identified by formula)</td>
<td>N/A (at least one component may fall into foregoing categories)</td>
</tr>
<tr>
<td>and stockpiling</td>
<td>toxicity</td>
<td>(lower threshold)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>agents</td>
<td>(upper threshold)</td>
<td>and purpose as determined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filling</td>
<td>N/A</td>
<td>N/A</td>
<td>Banned on basis of intent or end use</td>
<td>Banned on basis of intent or end use</td>
</tr>
<tr>
<td>of military</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ordnance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Working paper containing a compilation of statements made on the stagnation of the Committee's work, the absence of effective negotiations, and other related matters, at the formal meetings of the Conference of the Committee on Disarmament held from 20 February to 16 August 1973 (585th to 622nd meetings), (CCD/415)

23 August 1973

This year, for the second consecutive time, the Conference of the Committee on Disarmament will appear before the United Nations General Assembly with empty hands. The total sterility of its work in 1973 is all the more incomprehensible, and all the more difficult to explain, if one bears in mind the encouraging developments in the relaxation of international tension - developments which have created conditions that should logically have facilitated the achievement of substantial progress in the field of disarmament. It was precisely for this reason that eight of the non-aligned States members of the Committee on Disarmament felt obliged to point out, in March of this year, that "there is no reason which may justify any stagnation of the Committee's work and the current absence of effective negotiations" (CCD/396, para. 6).

The growing concern to which the present situation has given rise has been expressed not only in the present working paper, but also in various statements made throughout the session that is now coming to an end, the first of which was the statement made by the representative of Mexico at the opening meeting on 20 February 1973.

In the light of the foregoing considerations, the Mexican delegation has deemed it appropriate to prepare the present working paper, which contains a compilation - not exhaustive, but sufficiently illustrative - of the views which have been expressed on this question during the discussions of the Conference of the Committee on Disarmament. It would seem to be highly desirable that the vast majority (over a hundred) of the States Members of the United Nations which do not participate in the work of this Committee should, without having to scrutinize the hundreds of pages of verbatim records, be able to obtain a proper understanding of what, in the opinion of the Mexican delegation, has been one of the most striking aspects of the Committee's discussions this year, namely, the marked feeling of uneasiness and frustration aroused by the total paralysis of the negotiations which have been entrusted to the Committee.

Since the purpose of the present working paper is not in any way to stir up polemics, the criticisms which delegations of States members of one of the two military blocs represented in the Conference of the Committee on Disarmament have, from time to time, expressed concerning the conduct of States members of the other bloc, have deliberately been omitted from this compilation.

The statements reproduced are given in chronological order, with the sole exception of those made at the special meeting on 7 August, which are included at the end.
It is essential that the General Assembly should be fully aware of the gravity of the present situation, for which the only remedy would seem to be that, as long as it is not possible to convene a world disarmament conference, the Assembly itself, with the aid of its First Committee, should attempt without delay to delineate responsibilities, and to move on from abstract statements to exhortations that should be given concrete form not only through the identification of the procedural or substantive measures, whose implementation is considered to be essential immediately, but also, if it should appear to be necessary, by identifying those to whom the exhortations are addressed.

Perhaps the General Assembly, in the performance of this task, might find it desirable to give careful reconsideration, to the comprehensive programme of disarmament 56/ - in its resolution 2661 C (XXV) of 7 December 1970, the Assembly expressly recommended that this comprehensive programme of disarmament should be taken into account in the further work and negotiations on disarmament - particularly in the light of the provisions of paragraph 1 of part V, the relevant portion of which reads as follows:

"The General Assembly should consider annually the progress made in the implementation of the comprehensive programme. Every three years, the General Assembly should review the comprehensive programme and revise it as warranted. This will entail an evaluation of the over-all situation in the field of disarmament."

*

The representative of Mexico, at the opening of the session on 20 February 1973, stated that:

"The two questions which were given top priority in 1972, and which should be given the same priority in 1973 in the Committee's work, have now been studied exhaustively in all their aspects.

"The only thing needed, as the Secretary-General rightly said a year ago in referring to the cessation of nuclear tests, is to ascertain whether the two super-Powers are prepared to take the political decision which is necessary in each case. We believe that it should not take more than three or four weeks to reach a conclusion on this very specific point. We feel that we are entitled to require that they define their present respective positions with absolute frankness.

"Should it unfortunately prove that both super-Powers, or even one of them, is still unwilling to take this political decision, it seems to us that the Committee, instead of wasting any more time on academic deliberations, should suspend its consideration of those questions and leave it to the General Assembly to allocate responsibility as appropriate.

"Meanwhile, we would be better employed here in reviewing, in informal meetings, the great variety of suggestions concerning disarmament measures which have been submitted to the Committee in the course of its 11 years of work, with the object of selecting from among them some specific topics to which we could devote our immediate efforts with some prospect of achieving positive results" (CCD/PV.585, 3. Conclusions).

The representative of the Netherlands, on 6 March 1973, stated that:

"The world picture has changed considerably since the establishment of the Eighteen-Nation Disarmament Committee in 1961. Perhaps we can view the present world situation with somewhat more comfort and optimism than we were able to do some 12 years ago. It seems that countries are learning to live together in peace and harmony or, in any case, in a state of negotiation instead of confrontation. Co-operation among States in the fields of science, technology, economics and human relations is increasing ....

"How can the Committee on Disarmament fit into this global picture of a world striving for better and more enduring relations among nations? Does our Committee still have a role to play or is it doomed slowly to disappear?

"I do not believe it is to fade away ....

"The duty to make progress in the field of arms control and disarmament is still ours. We must in any case respond to the challenge of the last session of the General Assembly, which requested this Committee specifically to give first priority to its deliberations on a treaty banning underground nuclear weapon tests, and to continue negotiations, as a matter of high priority, with a view to reaching early agreement on effective measures for the prohibition of the development, production and stockpiling of chemical weapons and for their destruction" (CCD/PV.589).

The representative of Sweden, on 8 March 1973, stated that:

"In conclusion, I have to voice the concern of the Swedish Government at the slow rate of achievement in this Committee. Many other important disarmament questions remain to be solved, and the time has come to finalize the comprehensive bans on nuclear weapon tests and on chemical weapons. Agreements in these two fields would constitute truly major steps forward and would serve to justify the 11 years of existence of this negotiating body" (CCD/PV.590).

The representative of Canada, on 13 March 1973, stated that:

"... It is a disturbing anomaly that the last session of the United Nations General Assembly and the statements which have been made thus far in this session of the Committee on Disarmament have provided little evidence that progress is to be expected in the very area which that Assembly, like its predecessors, asked the Committee on Disarmament to treat with the highest priority - a comprehensive ban on nuclear weapon testing. This year marks the tenth anniversary of the partial test ban treaty. Every member of this Committee, and virtually every other Member of the United Nations, has at one time or another during this period proclaimed the urgent need to bring an end to nuclear weapon testing. The issues involved have been studied at length.
from every conceivable angle. Many proposals have been made for dealing with the problem; they have been modified, revised and recombined over and over. Some of these proposals have attempted to deal with the problem in its entirety, some — like the suggestions my delegation made two years ago for interim measures — have sought to make more limited advances which would, in due course, open the way to a comprehensive ban.

"There is a common factor to all these proposals which is as striking as it is discouraging; they have all been made by delegations other than those of the Co-Chairmen. Indeed, the two major testing Powers appear, in some ways, to have retreated from their positions of exactly 10 years ago.

..."We are here in this Committee, not for the sake of maintaining the Committee, but to achieve practical measures towards disarmament. We acknowledge the fact that this body will be under a serious handicap in this task until it includes representatives of all major military Powers. But it is still open to us to continue, in the meantime, to provide a valuable vehicle for disarmament negotiations. Equally, however, if this body fails to make meaningful progress on the issues before it within the near future, its reputation will suffer, frustration will grow and the Committee's future could, perhaps, be placed in jeopardy. We should all be alive to the dangers of such a development, but none of us more than the two Co-Chairmen" (CCD/FV.591).

The delegations of Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia submitted, on 14 March 1973, a memorandum (CCD/396), in which they stated, inter alia, the following:

"Conscious of the responsibilities of the Conference of the Committee on Disarmament to mankind and to the United Nations, they are increasingly concerned by the lack of tangible progress in the solution of the main disarmament problems entrusted to the Committee — a situation which became apparent during its last session and which the meetings of the present session have so far confirmed.

"While stressing that it is the duty of all members of the Conference of the Committee on Disarmament to contribute positively to the work of the Committee, it is their firm belief that primary responsibility rests with the two States which have been exercising jointly the chairmanship of the Committee and which also possess, to an overwhelmingly greater degree, nuclear weapons and other weapons of mass destruction.

..."It is their conviction that there is no reason which may justify any stagnation of the Committee's work and the current absence of effective negotiations, especially in the case of the following two questions, concerning which the United Nations General Assembly has repeatedly requested the Committee to deal with as matters of 'first' or 'high' priority:
"(a) Cessation of all nuclear-weapon tests, in conformity with the preamble to the Treaty Banning Nuclear-Weapon Tests in the Atmosphere, in Outer Space and under Water; and

"(b) Effective prohibition of the development, production and stockpiling of chemical weapons and the elimination of such weapons from military arsenals of all States, as agreed upon in article IX of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction."

During the final phase of the spring session and during the course of the summer session, a number of delegations referred to this same question.

The representative of Romania, on 15 March 1973, stated that:

"The Romanian delegation fully shares the concern displayed by many members of the Committee at the absence of progress in the disarmament negotiations and endorses the action of those countries which have given expression to that concern by submitting the memorandum of 14 March 1973.

..."

"The debates in this Committee and in the United Nations indicate the growing concern of States - and in this connexion I should like to refer to the recent remarks of the distinguished representative of the Netherlands - that the Committee's negotiations may lose sight of the ultimate objective towards which all our efforts should be directed, namely, general disarmament. The fact that, for several years past, we have shelved the problem of general disarmament and concentrated exclusively on a single subject has deprived our negotiations - as we are all aware - of an integrated outlook and a coherent programme of action, and has often drawn them into areas which are peripheral to the basic problems of disarmament" (CCD/PV.592).

The representative of Nigeria, on 22 March 1973, noted that, in 1972, "much work was ... accomplished, though in a rather preliminary and absolutely inconclusive manner, on the two urgent questions on our agenda - a nuclear test ban and a chemical weapons ban", and then stated that:

"On each of these two questions, a long stride has now been taken in terms of detailed technical analysis of the many-sided issues involved. We merely need to take the final step, without inhibition, in order to reach the much-hoped-for mutually acceptable conclusions. To do this, we once again need some form of self-prompting. And this was precisely why the Nigerian delegation whole-heartedly supported the memorandum submitted by the delegations of Burma, Egypt, Ethiopia, Mexico, Morocco, Nigeria, Sweden and Yugoslavia (CCD/396 dated 14 March 1973) expressing concern at the lack of tangible progress in the solution of the main disarmament problems entrusted to the Committee. The co-sponsors of that memorandum did not see it as a diatribe concerning any particular delegation, nor do we intend it to be so. We only tried to see things as they really are. What we expect from this moderate action is nothing but positive, as opposed to negative, reaction on the part of all concerned. We earnestly hope that our expectations in this regard will be adequately and very promptly met. We remain optimistic in this particular expectation" (CCD/PV.594).
The representative of Yugoslavia, on 27 March 1973, stated that:

"The statements which we have been listening to so far in the Committee on Disarmament during this year's session impose the conclusion that there is a high degree of consent among the members of the Committee on the following:

"First, that the present international political situation is favourable for achieving concrete results in the field of disarmament measures because of a number of positive developments in the international political scene which enhance détente and relaxation of tension in the world and in Europe in particular;

"Second, that the stagnation of the Committee's work, which is being felt for the second consecutive year, and the lack of progress in the solution of disarmament problems are in direct contradiction with the present international political situation and its current favourable trends;

"Third, that such a state of affairs can no longer exist side by side and that either the political situation should adequately be reflected in the Committee's work or the importance of the Committee's role as entrusted to it by the United Nations and the international community will be diminished."

After referring to the memorandum submitted by eight delegations (CCD/396), as well as to the statements of other representatives, the same representative added that:

"Similar concern, a feeling that the right momentum has been missed has found expression in statements of many other representatives.

"The irony of our position lies in the fact that we all recognize this contradiction and that none of us is satisfied with the present state of affairs in our Committee. However, there is a lack of political readiness to undertake joint action for removing this contradiction so that necessary progress is made in achieving practical measures of disarmament. Political readiness should no longer be assessed by eloquent speeches, which are heard so often in this Committee, but solely by practical proposals, which might serve for substantial negotiations which could lead to concrete results.

..."It does not seem, perhaps, inappropriate to repeat once again in the conclusion of my statement that, according to the view of my delegation, the state of affairs in the Committee is highly unsatisfactory.

"For my delegation and the other seven sponsors of /The/ memorandum (CCD/396), there is no valid reason which may justify the current absence of effective negotiations, especially in the case of two priority issues, namely, the prohibition of chemical weapons and the cessation of nuclear weapon tests. The authors of the memorandum consider that the main prerequisite for a turning-point in the existing situation could be accomplished only by a positive contribution of all members of the Committee and, in particular, by the joint and separate action of the two Co-Chairmen, upon whom rests the primary responsibility for creating the necessary conditions for the urgent beginning of the negotiating process on the two priority issues" (CCD/PV.595).

The representative of Brazil, on 3 April 1973, stated that:
"The current session of the Conference of the Committee on Disarmament, though it has only begun, has been marked by a mood of frustration and of criticism. Concern with what has been called lack of progress was expressed individually by several delegations and also collectively by some non-aligned countries.

"It has been asked whether the Committee has a role to play in disarmament, what the nature of that role is and how the Committee can best discharge its responsibilities.

..."

"Aware of the prospects for some effective disarmament negotiations elsewhere, and conscious, too, of the special and limited nature of the use that the super-Powers seem to be willing to make of this forum, my delegation would like to see the Committee continuing to play an active role in such fields as chemical weapons and the comprehensive banning of nuclear weapon tests" (CCD/PV.597).

The representative of Italy, on 12 April 1973, stated that:

"... the role that can be played by the Committee as the sole existing multilateral body qualified to conduct highly complex negotiations in the disarmament field has proved to be irreplaceable. We must therefore ensure that our Committee is equal to the tasks entrusted to it by the General Assembly and that the criticism to which it has been subjected from many sides must not go unheeded. On the contrary, such criticism must spur us on to impart a new dynamism to our endeavours and to redouble our joint efforts with a view to submitting to the next session of the General Assembly a more satisfactory report than now seems likely.

"The encouraging signs in the international situation today require of the Committee some fresh evidence of efficiency. In our opinion, this is the essential conclusion which can be drawn from the memorandum of the eight non-aligned States (CCD/396), and which all members of the Committee cannot but underwrite" (CCD/PV.600).

The representative of India, on 12 April 1973, stated that:

"The central role of the Committee in disarmament negotiations needs no reiteration. However, the present atmosphere prevailing in the Committee - during this, the twelfth year of its functioning - is characterized by growing disappointment among its many members over the lack of genuine progress in disarmament. This disappointment extends much beyond the narrow confines of the Committee and is shared by most Governments and peoples" (CCD/PV.600).

The representative of Pakistan, on 24 April 1973, stated that:

"Once again, since the inception of the current session of this Committee on 20 February, every distinguished speaker, including the Secretary-General of the United Nations and the distinguished Co-Chairmen, has felt that the Committee on Disarmament was resuming its work in an encouraging international situation and that the positive developments, such as peace in Asia and talks at Helsinki and Vienna, have created a more favourable political climate which should help the Committee on Disarmament in its efforts to achieve further
progress. This optimism gave rise to fresh hope. However, in two days' time we will draw the curtain down on the first part of our 1973 session with the painful awareness that mere optimism was not enough to achieve any progress on this item of high priority, as indeed on other matters on the agenda of our Committee" (CCD/PV.602).

The representative of Egypt, on 26 April 1973, stated that:

"The speakers who have preceded me have noted the existence of a general climate of détente in international relations at the present time ....

"But the same speakers have also, and we believe rightly, expressed their concern at the state of stagnation that has prevailed in the Conference for over a year. On several occasions they have found it necessary to draw attention to the dangers inherent in that state of affairs for the cause of disarmament in general and for the future of the Conference in particular. What is more, they have expressed their surprise that the Committee should be deadlocked at the very time when the international détente of which I have spoken is taking shape.

"This is felt to involve a certain contradiction and it is important for the success of our work to establish whether the contradiction is apparent or real. In other words, we must make an analysis of the causes, both direct and indirect, of the current lack of progress in our work in order to obtain a clear understanding of the present situation and make a better estimate of the possibilities for our future work" (CCD/PV.603).

The representative of Japan, on 26 June 1973, stated that:

"Basing themselves on the recognition that a series of recent developments in international politics indicates the easing of tensions between East and West, many delegates in this Committee pointed out that the climate of international politics, which constitutes an important basis for prompting disarmament negotiations, was improving, and expressed the earnest hope that concrete disarmament measures would soon be realized .... Despite this widespread recognition and expectation in and outside this Committee, substantial progress was not made in the deliberations during the spring sessions on important items, and about this many countries showed serious concern. This concern does not seem to be irrelevant to the movement directed towards the reassessment of the way this Committee should run" (CCD/PV.607).

The representative of the Netherlands, on 28 June 1973, stated that:

"In the past, this Committee has written a record of long but successful negotiations. At present one cannot escape the impression that the Committee on Disarmament has lost its momentum, much to the regret, I assume, of all delegations to this Conference.

"A lack of progress here does not merely mean a standstill, but in fact retrogression. Not only the future of disarmament negotiations, but also the viability of agreements already reached is at stake" (CCD/PV.608).
The representative of Morocco, on 3 July 1973, stated that:

"The lack of progress within our Committee in the field of nuclear disarmament, the stubborn way in which certain nuclear States continue to perfect and multiply the devices of weapons of mass destruction, and the non-participation of two nuclear States in the disarmament negotiations are at the origin of the present situation, which is characterized by the stubborn continuation of tests in all environments" (CCD/PV.609).

The representative of Czechoslovakia, on 10 July 1973, stated that:

"The first stage of the summer session has shown that the present favourable development of international relations may have a positive impact on the negotiations in the Committee on Disarmament, but is no substitute for a concrete contribution by each Government to the solution of the most important questions of disarmament. We shall achieve a positive result only if we are able to take advantage of this favourable development in relations between States in order to elaborate further specific agreements.

..."

"Both in and outside this Committee, everyone is waiting impatiently for the present session to make substantial progress in the solution of the main problems on the Committee's agenda, especially as regards the prohibition of chemical weapons. To achieve a rapid solution to this problem, the Committee must, in the Czechoslovak delegation's view, concentrate all its efforts" (CCD/PV.611).

The representative of Romania on 17 July 1973, stated that:

"At the risk of being repetitive, we should like to say, once again, that, in leaving aside the priority questions of disarmament, especially nuclear disarmament, and dealing with isolated aspects of the problem, the Committee has been increasingly losing its sense of proportion.

"It must be frankly stated that the critical situation in which the Committee finds itself and which, fundamentally, has to do with the political will of States, is due to the ineffectiveness of the Committee, which is prevented from dealing with the most urgent problems that should be the subject of any genuine disarmament efforts.

"As we have many times declared, a radical change in the Committee's approach to disarmament problems, and in all its work, is urgently necessary.

"Such a step would be extremely easy in view of the favourable developments in international life" (CCD/PV.613).

The representative of Hungary, at the same meeting, stated that:

"... The lack of any progress in the course of our sessions last year ... caused a certain concern in public opinion, and it was further deepened during the spring session of this year, when it became apparent that work in the Committee had, in fact, come to a virtual standstill ...."
"The situation that prevailed in the Committee at the end of the spring session is still persisting even now ... a strong fear is already taking root: the fear that the Committee will not be able to do anything but report again to the General Assembly, and now, for the second consecutive time in the last few years, that the characteristic features of the Conference as a whole are stalemate and stagnation" (CCD/PV.613).

The representative of Mongolia, on 26 July 1973, stated that:

"In a few weeks' time, this Committee will have to report on the results of its work for this year to the General Assembly, which has requested us, the members of the Committee, 'to continue negotiations, as a matter of high priority, with a view to reaching early agreement on effective measures for the prohibition of the development, production and stockpiling of chemical weapons and for their destruction' (General Assembly resolution 2933 (XXVII)).

"Negotiations are continuing, but unfortunately no positive results are apparent - at least up to today - in the matter of reaching agreement on this vitally important issue.

"The Committee finds itself in this far from enviable situation despite important positive developments which are conducive to international détente, encourage a spirit of negotiation and mutual understanding and thus create favourable conditions for our efforts to find solutions to the urgent problems of disarmament.

"Given a positive approach by all sides, conditions in this very Committee are also calculated to promote the preparation of the necessary basis for working out a concrete agreement on the question under discussion" (CCD/PV.616).

The representative of Yugoslavia at the same meeting, stated that:

"In our Committee, too, we are confronted by stagnation, stalemate and frustration. What is paradoxical is that United Nations efforts seem to be stuck at a time of growing détente in the world which should be of a nature to stimulate and facilitate multilateral negotiations and, in particular, those concerning the questions of arms control and disarmament.

..."

"As far as concerns the work of the Conference of the Committee on Disarmament as the only multilateral negotiating body linked with the United Nations, I have no choice but to refer again to the assessment made in the eight-nation memorandum of 14 March 1973 (CCD/396) on the occasion of the Committee's twelfth anniversary. The disappointment at the lack of progress and at the stagnation in which the Committee finds itself for the second consecutive year has been expressed in the statements of a number of other delegations. In the meantime, unfortunately, nothing has happened to remedy this state of affairs and, what is more discouraging, there seem to be no prospects of finding a way out of this impasse."
"As a matter of fact, in its consideration of the two priority issues on its agenda, namely, the cessation of nuclear weapon tests and measures for the prohibition of the development, production and stockpiling of chemical weapons and for their destruction, the Committee has been moving for quite some time in a vicious circle. We have been listening to many statements which are often repetitions of previous ones or, at best, contain some additional analysis and comments which are not very productive because they are not backed by concrete proposals. In other words, we are stuck because we have long since reached the point where the expression of political readiness is decisive in order to move from the phase of exploration to the negotiating process itself.

"The question we have to raise now is, how much more time is needed for this process to bear fruit in regard to the two items I have just mentioned. Or let me put it differently. Does it mean that the Committee's inability to come out of its stagnation is a sign of a deep crisis in which it finds itself, a polite way, perhaps, of warning the world community that it has come to the end of its usefulness? We would like to believe that this is not the case. With all its short-comings, the Committee can still play an important role in multilateral disarmament negotiations, pending, of course, the time when it can be made more representative, more negotiation-oriented and more democratic in its procedure and method of work in accordance with present-day requirements, or until it is replaced, perhaps, by some other multilateral negotiating body which the States Members of the United Nations would like to have." (CCD/PV.616)

The representative of Bulgaria, on 31 July 1973, stated that:

"The delegation of the People's Republic of Bulgaria again deems it necessary to state its view that the favourable international situation should be reflected also in the work of the Committee on Disarmament, and that this important and authoritative international forum should take advantage of that situation to move forward in matters of disarmament. We hope that the change which has set in in international life will find its echo here, too, and will be reflected tangibly in the preparation of new and significant agreements on a number of vitally important disarmament questions." (CCD/PV.617)

The representative of Sweden, on 9 August 1973, stated that:

"In my statement of 5 July, I had the great - and frankly somewhat rare pleasure - to comment on certain recent developments that promised to carry the cause of disarmament forward in a positive direction. I am referring to the Brezhnev-Nixon agreement to make serious efforts within 1974 for curtailing the increase in strategic weapons numbers, as well as their further 'qualitative' development. This, we believed, constituted a gateway to a land of new promise for all disarmament efforts.

"The climate of détente does not seem, however, to lead to new purposive action with any noticeable speed. This year also the Committee will probably appear empty-handed before the General Assembly. I want to devote this statement to a preview of issues which my delegation deems it necessary to pursue, e.g. through resolutions, in the General Assembly this autumn. First
of all, action must be urged on the avowed musts on the agenda of the Committee and the United Nations, a comprehensive test ban and a convention on chemical weapons. Of these, without any doubt, efforts to achieve an end to the nuclear arms race is the most important. But, besides these top priorities, there is a wide spectrum of disarmament proposals which we have left in oblivion for too long. Certainly, our Governments are not incapable of dealing with burning world issues in a more efficient manner than the myopic focusing on only one or two of them at a time and, even that, only at the kind of snail's pace which we seem to have become accustomed to here." (CCD/PV.620)

On 7 August 1973, at the 619th meeting, which was regarded as a special meeting to mark the completion of 10 years since the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water was opened for signature in Moscow on 5 August 1963, statements were made by the representatives of 20 member States. A large number of these representatives expressed in various ways their concern at the lack of progress towards a comprehensive test ban.

The representative of Mexico stated that:

"It would seem inescapably clear from what I have just stated that the verdict of history will not be very favourable to the position adopted so far by the nuclear Powers with regard to the partial test ban treaty. Not to put too fine a point on it, I would say that this position has dashed the hopes which mankind had placed in the treaty when it was opened for signature 10 years ago. Although the treaty has had beneficial effects in preventing the radioactive contamination of the environment, its value as a disarmament measure, even within the so-called collateral measures, has unfortunately been non-existent.

"It is a lamentable fact that the Original Parties have forgotten their own words, expressed in the Committee on Disarmament in July and August 1963, when, as I recalled at the beginning of my statement, they rightly emphasized the modest scope of the Moscow treaty and the fact that its 'real significance' would depend on the 'goodwill' which they themselves managed to display in order to contribute effectively to the attainment of the purposes solemnly enunciated in the preamble to the treaty.

"The nuclear Powers have scarcely two years left in which to make the radical change of attitude we consider essential. For it must not be forgotten that, under article VIII of the non-proliferation treaty, a conference of parties is to be held in 1975, in Geneva, 'in order to review the operation of this treaty with a view to assuring that the purposes of the preamble and the provisions of the treaty are being realized'. There is a serious danger that, if the current deplorable situation were to continue until the time when the conference is held, the future status both of the partial test ban treaty - which, though it does not provide for the holding of a review conference, does contain provisions permitting the withdrawal of any of the parties - and of the non-proliferation treaty would be seriously jeopardized.
"It is to be hoped that the nuclear Powers realize this and that, in the relatively short time still available to them, they will heed the voice of world public opinion, which for more than 15 years has made itself heard so urgently and unequivocally in the numerous resolutions adopted by the General Assembly of the United Nations, the most representative organ of the international community.

"We are fully aware that general and complete disarmament is a goal which can be attained only as the culmination of a series of agreements and measures aimed at achieving the gradual limitation, reduction and elimination of weapons, beginning with nuclear weapons. But we are also firmly convinced that among those measures there is none in respect of whose adoption there could be such an unjustified delay as has occurred in relation to the measure promised in the preamble to the Moscow treaty. We are convinced that, as the General Assembly has rightly said, there is no valid reason for postponing the permanent prohibition of all nuclear weapon tests in all environments. The tenth anniversary of the 1963 treaty is, indeed, a sad occasion. It is for the nuclear Powers alone to ensure that such a discouraging one will not occur again."

The representative of Nigeria stated that:

"It seems evident that the bright hopes attached to the signing of the partial test ban treaty in 1963 have in 1973 been dashed to pieces. In order to revive the hopes of mankind in this matter, the Nigerian delegation would like to urge those concerned to pursue two essential steps with all honesty and sincerity. First, we strongly urge all the States which - and incidentally they remain non-parties to the partial test ban treaty - are continuing nuclear testing in the atmosphere to sign the treaty and put an end to their venture, which does mankind no good. Second, we equally strongly urge the two super-Powers which now test underground to apply the much-sought-after brake as well as to team up with all other States in seriously negotiating a comprehensive test ban treaty, thus carrying the partial test ban treaty to its logical conclusion. The partial test ban treaty should not be allowed to remain partial indefinitely."

The representative of Sweden stated that:

"While the date 5 August 1963 is recalled with partial rejoicing, the date 5 August 1973 must be marked as a day of mourning. When, on 12 April this year, I did not hesitate to use such a strong term (CCD/PV.600), it was because we - the majority of the world's nations who have no nuclear weapons in our hands and conduct no tests to acquire them - consider that we are facing a breach of promise on the part of the super-Powers. They not only signed a pledge to seek the discontinuance of all tests. They also led us to believe that the Moscow treaty would reduce the nuclear testing and impose limits on nuclear weapons development.

"As a matter of fact, in August 1973, a closing of the test series that sustain the nuclear arms race seems to be farther away than ever."
"We can no longer be made to believe the generalities which express some innermost will to cease such testing but profess impotence to carry out that will, due to some residual differences as to how to organize foolproof verification. This reproof is addressed to both the super-Powers. If one of them - perhaps not here, but in the framework of bilateral talks - would signal to the other a definite willingness to stop the nuclear arms race, they should certainly be capable of technically overcoming or politically setting aside the minimal uncertainties which remain in regard to verification."

The representative of Pakistan stated that:

"On 5 August 1963, the ... Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water was signed in Moscow. It was welcomed as an important and essential first step towards safeguarding man's environment from contamination by radioactive substances. Implicit in the Treaty was the hope that it would contribute towards slowing down the general arms race by imposing limits on development of nuclear weapons; that it would contribute towards checking the spread of nuclear weapons to other nations and thereby facilitate progress towards disarmament.

"However, what gave this Treaty its special significance was the solemn pledge made by the three nuclear Powers, designated in the Treaty itself as the 'original parties' - the United Kingdom of Great Britain and Northern Ireland, the United States of America and the USSR - that they would seek to 'achieve the discontinuance of all test explosions of nuclear weapons for all time'. This was a pledge given not only in the preamble, but further reinforced in article I (b) of the Treaty by clearly stating their determination to conclude a treaty 'resulting in the permanent banning of all nuclear test explosions, including all such explosions underground'.

"Ten years have passed, but the pledge remains unfulfilled. The achievement of a comprehensive test ban remains at best a declaration of intent only by the three 'Original Parties' to the Treaty. Not only have several opportunities to redeem that pledge been missed since 1963, but two out of the three Original Parties have continued intensive underground testing. Contrary to the hopes expressed by them, the partial test ban treaty has not slowed down the arms race between the United States and the USSR except for the restrictions imposed on the development of very large thermonuclear weapons.

"On this special occasion, which marks the tenth year of existence of the Treaty, it is not our intention to recriminate, but to urge the nuclear Powers, and especially the Original Parties to the Treaty, to grasp the present opportune moment in international relations to fulfil their own pledge."

The representative of Canada stated that:

"Indeed, the negotiating road towards a comprehensive test ban over the past 10 years has been a long and tortuous one; in fact, at times we may wonder if we are still on the road at all!"
"Where then do we find ourselves today as we mark the tenth anniversary of the partial test ban treaty? On the one hand, we still can look with some satisfaction at a major achievement of the partial test ban, namely, the adherence of the world's three most advanced nuclear Powers. They have fully respected the Treaty's obligation not to carry out nuclear tests in the atmosphere, in outer space or under water and, as a consequence, the world has witnessed a considerable drop in the level of man-made radioactive contaminants when compared to the peak period of nuclear testing. On the other hand, the world is also witness to the fact that two nations continue to test in the atmosphere, despite widespread concern and despite the very treaty whose anniversary we are observing today. As I made clear in my statement in the Committee on 3 July (CCD/PV.609), my delegation continues to believe that the nuclear Powers which have been carrying out tests in the atmosphere should stop this particular type of testing and associate themselves with the test ban. But we also note with regret that the world's two super-Powers have continued to carry out nuclear tests at an undiminished rate, albeit underground. From the viewpoint of the arms race, therefore, the situation remains static.

"On this day, observing the tenth anniversary of the partial test ban treaty, it is the duty of all of us to do what we can to encourage the accession of all nations to the partial test ban treaty as well as continue to press all nuclear Powers to commence serious and active negotiations towards the ultimate goal - 'the discontinuance of all test explosions of nuclear weapons for all time'."

The representative of India quoted the following part of the message of the Prime Minister of India to the International NGO Conference on Disarmament, held at Geneva in September 1972:

"In this nuclear age, the question of disarmament is the most vital and urgent one confronting mankind. The spiralling arms race in nuclear and other weapons of mass destruction raises fundamental issues which no one can ignore, for it threatens the survival of the human species, indeed of all life on our planet. And yet there is helpless acceptance of these fearful weapons as part of our daily lives and a complacent acquiescence in the pernicious concept of the balance of terror. The irony is that we see the goal, we have the means, but we lack the political will and mutual trust necessary to take one big step forward."

The same representative then added that:

"What we need today is the political will and mutual trust ..."

"We hope that the Committee on Disarmament will continue to press, with even greater determination, for the urgent solution of the problems of nuclear disarmament and other weapons of mass destruction, especially chemical and biological, whose horrors have come to be fully understood by the international community only in recent years. Absence of war is not peace. Peace and progress are entirely dependent on disarmament."
The representative of Japan stated that:

"I am convinced that, in walking the difficult path of disarmament, it is necessary to proceed step by step. In this sense, the partial test ban treaty was an important landmark, and we shall have to continue our progress towards a next landmark, that is, a comprehensive test ban. As an occasion to realize this, I appreciate highly the significance of today's special meeting.

"While 5 August is the day of hope when the reason of mankind to avoid a nuclear war bore fruit in the form of the partial test ban treaty, I cannot help but recall 6 and 9 August as dark days when nuclear weapons were in fact used, bringing horrors to mankind. According to the figures recorded by our government organizations, as of 1 August 1973, the number of deaths caused by the nuclear weapons dropped on Hiroshima and Nagasaki has reached 128,444 (in Hiroshima 81,753 and in Nagasaki 46,691); this shows a total increase of 2,808 in the number of these deaths since last year. Thus the trend of the increase in the number of the victims shows no sign of being blunted yet, 28 years after the nuclear explosions took place.

"The partial test ban treaty, in its preamble, expresses /the/ intention /of the Original Partie/ to seek 'to achieve the discontinuance of all test explosions of nuclear weapons for all time, determined to continue negotiations to this end ...'. After the decade which has passed since the signing of the partial test ban treaty, a comprehensive test ban is the task which remains to be achieved. On the significant occasion of this special meeting, I wish to call upon the distinguished representatives of this Committee to renew our realization of what horrors the use of nuclear weapons can bring to mankind and to promise among ourselves to do our very best in making another important step in order to avoid nuclear war forever through a prohibition of all nuclear weapon tests in all environments."

The representative of Brazil stated that:

"Unfortunately, the general framework of world-wide nuclear disarmament in which the Moscow treaty should find its place is still a desire in the hearts of peoples and an abstract structure in the minds of negotiators, rather than a reality or at least a concrete plan in the process of execution.

"The Moscow treaty, significant as it was from a political point of view and from the point of view of the preservation of the environment, has never been considered by any of its signatories as anything but a starting point, albeit a necessary and promising one.

"It is the feeling of my delegation that, because this treaty has stood practically as an isolated achievement, one can hardly pin the responsibility for its failure to command universal adherence exclusively on those who kept aloof from it. However much we may deplore nuclear weapon explosions that are still taking place in the atmosphere and, indeed, also those which are taking place underground, we cannot ignore the fact that effective negotiations involving all members of the United Nations to end such tests can hardly be successful if carried out with no real progress in nuclear disarmament and, one might add, general and complete disarmament under effective international control."
On this day, therefore, that should be one of celebration, it is fitting to temper our satisfaction with the realization of the immense difficulties that have prevented the hopes entertained 10 years ago from coming to fruition, and to dedicate ourselves to contributing, in our multilateral efforts, towards reducing such difficulties and achieving our broader goals."

The representative of the Netherlands stated that:

"The will towards further negotiations aimed at general and complete disarmament and, in particular, at nuclear disarmament, was very clearly expressed in the preamble to the partial test ban treaty. So far, the solemn pledges embodied in that preamble have not been fulfilled, even though some partial arms-control agreements have since been concluded. The partial test ban treaty has not yet been complemented by the conclusion of a comprehensive test ban.

"To our regret, some countries have not yet acceded to the partial test ban treaty and have continued their testing in the atmosphere. Other nuclear Powers have continued testing underground. Although 10 years ago several countries were of the opinion that a ban on atmospheric testing would curtail the possibilities of developing new weapons, in practice the partial test ban treaty has proved to be mainly an important health measure. The qualitative arms race between the main Powers has not been slowed down by the partial test ban treaty."

The representative of Egypt stated that:

"When the Moscow Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water was concluded on 5 August 1963, it was welcomed with a broad wave of satisfaction that promptly led to a flow of accessions by States, including my own, to that new legal instrument. The Treaty unquestionably reflected a certain balance in the forces of deterrence and heralded a new trend in disarmament from the general to the particular and from the global to the partial. Moreover, while the Treaty did not change anything at the technological and military levels, it none the less evinced the signatories' intention to establish their relations on more solid foundations than had been the case hitherto, and it raised immense hope throughout the world. It was regarded as a first, though hesitant, step towards curbing the development of nuclear weapons and, to some extent, preventing their spread, reducing the danger of radioactive fall-out, opening up opportunities for negotiation and further agreements in the field of disarmament in general and the banning of underground tests of nuclear weapons in particular and, lastly, reducing the tension between the super-Powers. The final objective of the parties to the Treaty was, after all 'to achieve the discontinuance of all test explosions of nuclear weapons', including underground tests, and the parties were determined 'to continue negotiations to this end'.

"But it did not take long for that hope to be dashed. The debates on the banning of any kind of nuclear test, debates which have already been going on for more than 10 years, have still not produced any results. On the contrary, the number of nuclear weapon tests has gone on increasing since 1964, and this has not failed to create a situation that is full of contradictions, for it can be seen that the constant growth in nuclear arsenals does not in any sense
help those involved to secure an adequate degree of national security - quite the opposite.

"Aware of these considerations and anxious to see that international peace and security are built on firm foundations, disarmament being prominent among them, my delegation, like so many others, has since 1964 unceasingly stressed the pressing need for a ban on all nuclear weapon tests, including underground tests. To that end, it has unfailingly submitted the proposals and suggestions it considered useful or timely, while taking part in the efforts made in this respect by the group of non-aligned countries represented in the Committee, and by the Conference itself. One cannot but sincerely deplore the fact that all these endeavours have not borne fruit, just as, generally speaking, one cannot but deplore the stagnation into which the work of our Conference has fallen in recent years."

The representative of Romania stated that:

"The tenth anniversary of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water affords our Committee, which has been concerned with the matter since its establishment, a suitable opportunity to review the efforts made, and the results achieved, in the field of nuclear weapons as a whole. In our view, the most important consideration at present is to ensure that this anniversary throws into relief, as clearly as possible and in the light of the new international realities, the Committee's basic immediate and long-term tasks, and that it leads to a reaffirmation and stimulation of the political will of States to do everything they can to achieve effective measures in the field of disarmament.

"The Romanian delegation takes the view that the best way of celebrating the anniversary of the Treaty is for the Committee to use all the means at its disposal to proceed to the negotiation and adoption of measures designed to achieve the complete banning and elimination of nuclear weapons and their carriers."

The representative of Ethiopia stated that:

"The tenth year of the partial nuclear test ban treaty has come and gone without a comprehensive treaty. This failure to fulfil an essential undertaking embodied in the treaty, to render comprehensive its partial coverage, is a stark fact whose historical consequences in terms of endangering the security and survival of humanity are incalculable. Allow me, Mr. Chairman, to express the concern and disappointment of the Ethiopian delegation.

"The failure during the last decade both to respect and complete the provisions of the partial test ban treaty has been a matter of anxiety for many countries, including our own. Nuclear tests of the past 10 years, those exploded in the atmosphere or underground and of whatever size and power, have effectively fuelled the nuclear arms race, especially its qualitative aspects, and continue to inculcate in the non-nuclear Powers the belief that national security can only be assured by the attainment of nuclear status. Thus today, 10 years after the conclusion of the partial test ban treaty, it is with regret and considerable apprehension that we observe nuclear tests taking place systematically, both in the atmosphere and underground."
"A greater disappointment is the awareness that even signatories of the partial test ban treaty no longer have the political will and purpose to fulfil the obligation they assumed so many years ago to negotiate a comprehensive treaty prohibiting nuclear tests; and allow their political vision to be obscured by the pursuit of a perfect, watertight monitoring system of seismological events that remains illusive and is hardly attainable.

"Near-nuclear States have not been reassured by this unexpected ten-year delay. Non-parties to the partial test ban treaty have been insensitive to appeals and continue to test even in the prohibited environments, sustained by the fact that the size and number of nuclear weapons tested underground during this period are both formidable and considerable.

"There is the further danger that this deterioration, unless dramatically reversed, would undermine the Treaty on the Non-Proliferation of Nuclear Weapons, and thus threaten the Committee's principal achievement.

"Would it not be the main responsibility of the two Powers whose nuclear stockpiles are already enormous to take decisive action to arrest the deterioration and reverse the process? It is with this in mind that the Ethiopian delegation urges the nuclear Powers fully to re-examine the question in the light of the new chapter that is opening in the world's history, a chapter of wider international co-operation in all fields of activity, of enhanced concern for protecting the environment and conserving the resources of the world, of deeper consciousness of human solidarity and increased recognition and acceptance of the role and responsibility that all peoples, nations and regions have in assuring the security and prosperity of our planet.

"There could be no firmer step towards a more positive and creative turn of direction in international relations than a deliberate and agreed halt of the nuclear arms race. It is vital therefore that the nuclear Powers stop all testing and negotiate a comprehensive treaty for the prohibition of nuclear weapon tests, so that the gains of humanity in the sphere of disarmament would not be dissipated and put at risk by missed opportunities to take this first necessary step."
Detection and identification

Contrary to the situation of a few years ago, the Conference of the Committee on Disarmament documents and the separate studies of individuals and institutes of the last two years on the detection, location and identification of underground nuclear explosions seem more and more to lead to common conclusions. The earlier controversies on the existing and potential capabilities of a system of observational stations (arrays included) have apparently disappeared, and most parties now agree that, under otherwise normal conditions, events down to yields of several kilotons in hard rock can be identified anywhere in the northern hemisphere.

These converging results of mutually independent studies are illustrated in the accompanying figure. The conclusions of different groups of investigators have been plotted according to the scheme used in the earlier Netherlands working paper CCD/323 of 18 March 1971. 57/ Several points may be stressed here:

1. A nearly complete detection and location of $m_b \geq 4.0$ events on the northern hemisphere seems to be possible now (CCD/388). 58/ Although this task is not yet being performed on a routine basis, theoretically the capability seems to be present when all information from NCAA, ISC, WWNSS and the individual arrays is combined.

In an actual experiment (the International Seismic Month), it was concluded from a preliminary analysis that the data from current systems, when integrated, have a 90 per cent probability of detecting and locating Eurasian events at about $m_b \geq 4.2$ (CCD/406).

2. The identification capability of the WWNSS in the northern hemisphere is down to yields of about 10 to 20 kilotons (Basham-Whitham, 1971). For particular cases and selected readings, this capability has been extended to yields of 7 kilotons and more in hard rock, with a potential extra extension down to 4 kiloton yields (Marshall-Basham, 1972).

3. Spectral analysis of the direct P-waves, using short-period arrays only, seems to have a considerable potential for identifying seismic events (CCD/380). 58/


58/ Ibid., Supplement for 1972, document DC/235, annex B.
In the Canadian working paper (CCD/406), an identification method is described in which several identification criteria are used in combination with each other, like the $M_s - m_b$ method, spectral analysis and depth of focus. In the present working paper, it is concluded that there is a high probability that explosions with body-wave magnitudes greater than $m_b = 4.5$ would have been defined as such. Furthermore, there is an appreciable probability of identifying explosions of $m_b = 4.2$ if no evasion techniques are applied.

The identification capabilities of the large arrays LAO (LASA), NOS (NORSAR) and ALP (ALPA) are well known and in the range of 2 to 4 kilotons in hard rock at teleseismic distances (CCD/388).

5. The VLPE (Very-Long-Period Experiment) network performance (called LPZ in CCD/323) has reached a value of 5 kilotons and, with a small extension which will be realized in the near future, will be lowered to values of 2 to 3 kilotons in hard rock (CCD/388).

With the present network of standard stations, arrays and VLPE-stations, an identification level has thus been reached that is comparable to the detection level, as was foreseen in the Netherlands working paper CCD/323. This analysis, together with the analysis of evasion possibilities set out hereafter, formed the basis on which the Netherlands Government concluded that obligatory on-site inspections would not change in any significant way the number of events which can be identified (CCD/PV.608).

Evasion

As was pointed out above, the detection/identification threshold for underground nuclear explosions in hard rock in the northern hemisphere lies in the yield-range of 2 to 3 kilotons.

It remains possible to evade detection and identification by firing test devices in dry soil of sufficient thickness. Yields of 10 kilotons and less may pass undetected in such a way. However, in order to be sure that no cratering will occur which could be detected by satellites, a safety margin would have to be taken into account. Moreover, there are only relatively few areas where thick layers of dry alluvium are present. In United States working paper CCD/388, an estimated yield limit of 1 to 2 kilotons is mentioned as a pre-condition for avoiding detection of a tamped shot in low-coupling media, with a possible maximum of 10 kilotons if sufficiently deep low-coupling media are available. This cratering threshold is of the same order of magnitude as the seismological detection/identification threshold for explosions in rock. It may be noted that further improvements in seismic capabilities would affect the threshold for explosions in hard rock but not necessarily the threshold for explosions in dry soil.

Working papers CCD/388 and CCD/404 describe some other evasion techniques. As far as we know, none of these have been proved in practice, at least not for the mentioned possible yields.

For example, there is the theoretical possibility of masking the spectral
properties of the P-wave signal by executing a sequence of explosions in order to stimulate an earthquake. Until a manifestly successful experiment has been carried out in this way, it would be hard to believe that this technique would present a practical possibility for evasion.

Until now the maximum yield of a test in a decoupling cavity has been 0.35 kiloton. The yield of 50 kilotons, which document CCD/388 mentioned as a possibility, does seem to be high from a practical point of view, since very great cavities would be necessary. Even if such cavities could be made, they would cost a great deal and the activities involved in making them would probably not be easy to hide.

Other evasion techniques mentioned in document CCD/338 are:

(a) Timing of an explosion with a nearby earthquake of at least one unit of magnitude higher; and

(b) Timing of an explosion within the coda of a very large earthquake.

Even with an optimal choice of location of the test sites with respect to the seismic zones, it is probable that crucial moments for firing will not occur more than a few times a year or even only once in several years. According to document CCD/388, the yield limits for these procedures are 50 and 100 kilotons respectively.

Both of the above-mentioned evasion techniques would require instantaneous action, that is, all procedures needed for the firing, including precautionary safety procedures, must be set and held more or less indefinitely for immediate action. Presumably the firing must be executed automatically within tens of seconds or less from the time of the first disturbance. For a reasonable programme, a considerable number of test sites with armed nuclear devices would be necessary when using these evasion methods.

Moreover, certainty of non-detection and non-identification could not be gained in advance. A misinterpretation of the magnitude of the "concealing" earthquake could lead to the artificial signal being detected. Also, good results of a special study by matched filtering or frequency-analysis techniques, or an unexpected but sometimes observed abnormal transmission of energy in directions of certain key stations in the network cannot be ruled out in advance. These considerations imply that a would-be violator of an underground test ban, in order to play safe, would have to decrease the above-mentioned yield limits of 50 and 100 kilotons to fractions of these yields if, in practice, the methods could be used at all.

It is important to bear in mind that obligatory on-site inspections, if based on seismological data, would not significantly change the above-mentioned possibilities for evading a test ban.

As to the swamping technique, described in document CCD/404, in which long-period surface waves of nuclear explosions would be hidden in the surface waves of large earthquakes while allowing detection of the P-waves of the explosion, the following preliminary remarks may be made. More information on this evasion technique would, however, be most welcome.
An extension of table (3) of document CCD/404 shows that, in order to hide an explosion of the order of 10 kilotons (equivalent to magnitude $m_{0.75 - 5.0}$ when fired in hard rock), a masking earthquake with a magnitude of $m_{7.8 - 8.1}$ would be needed when use is made of long-period arrays. Such an earthquake occurs on the average only once a year. This does not seem to be a practical basis for the execution of a test programme for yields of about 10 kilotons. On the other hand, the improvement in knowledge about the local structure of the earth crust and the upper mantle in the northern hemisphere is such that matched filtering seems to have great potential for discriminating between surface waves coming from different directions. Also, it may be pointed out that, while using the above-mentioned evasion technique, P-waves are still registered, allowing for other criteria to be used like spectral analysis and measurement of focal depth.

Conclusions

1. Obligatory on-site inspections would not enhance the identification possibilities significantly.

2. Realistic possibilities of evading an underground test ban seem to exist for yields up to about 10 kilotons. Significant improvements and extension of the seismological hardware will probably not change this situation fundamentally. On the other hand, improvements in counter-evasion techniques like spectral analysis, matched filtering and measurement of focal depth could be quite useful.

3. An intensified international exchange of those seismic data which are used for identification of events is needed on a routine basis.

-232-
HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES


КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Напишите со списки об изданиях в нашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Litho in United Nations, New York

Price: $U.S. 10.00

(or equivalent in other currencies)