REPORT
OF THE
CONFERENCE OF THE
COMMITTEE ON DISARMAMENT

Volume II

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New York, 1978
NOTE

Symbols of the 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 present volume contains annex II to the report of the Conference. The report and annexes I, III and IV appear in volume I.
# ANNEX II

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

<table>
<thead>
<tr>
<th>Document No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCD/547</td>
<td>Letter dated 16 January 1978 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 thirty-second session</td>
<td>1</td>
</tr>
<tr>
<td>CCD/548</td>
<td>Italy: working paper on the question of the drafting of a comprehensive programme of disarmament</td>
<td>5</td>
</tr>
<tr>
<td>CCD/549</td>
<td>Canada, Germany, Federal Republic of, Italy, Japan, Netherlands and United Kingdom of Great Britain and Northern Ireland: draft programme of action for the special session of the General Assembly devoted to disarmament</td>
<td>10</td>
</tr>
<tr>
<td>CCD/550</td>
<td>Argentina, Egypt, Ethiopia, India, Peru, Yugoslavia and Zaire: special session of the General Assembly devoted to disarmament: non-aligned working document containing the draft declaration, programme of action and machinery for implementation</td>
<td>14</td>
</tr>
<tr>
<td>CCD/551</td>
<td>Schedule of meetings of the Conference of the Committee on Disarmament for the spring session</td>
<td>15</td>
</tr>
<tr>
<td>CCD/552</td>
<td>Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Mongolia, Poland and Union of Soviet Socialist Republics: working paper on the comprehensive programme of disarmament</td>
<td>17</td>
</tr>
<tr>
<td>CCD/553</td>
<td>Romania: working paper on the draft comprehensive programme of disarmament</td>
<td>21</td>
</tr>
<tr>
<td>CCD/554</td>
<td>Sweden: elements for inclusion in the programme of action of the special session of the General Assembly devoted to disarmament and in its documents relating to the machinery for disarmament negotiations</td>
<td>24</td>
</tr>
<tr>
<td>Document No.</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>CCD/555</td>
<td>Nigeria: suggestions for inclusion in a comprehensive programme of disarmament</td>
<td>25</td>
</tr>
<tr>
<td>CCD/556</td>
<td>Pakistan: working paper submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament: declaration on disarmament</td>
<td>29</td>
</tr>
<tr>
<td>CCD/557</td>
<td>Pakistan: working paper submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament: programme of action on disarmament</td>
<td>30</td>
</tr>
<tr>
<td>CCD/558 and Add.1</td>
<td>Report of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and to Identify Seismic Events</td>
<td>31</td>
</tr>
<tr>
<td>CCD/559</td>
<td>Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Mongolia, Poland, Romania and Union of Soviet Socialist Republics: draft convention on the prohibition of the production, stockpiling, deployment and use of nuclear neutron weapons</td>
<td>208</td>
</tr>
<tr>
<td>CCD/560</td>
<td>Mexico: some fundamental principles and norms for inclusion in the declaration on disarmament envisaged in the draft agenda of the special session of the General Assembly devoted to disarmament, approved by the Preparatory Committee on 18 May 1977</td>
<td>210</td>
</tr>
<tr>
<td>CCD/561 and Add.1</td>
<td>Mexico: outline of a draft final document of the special session of the General Assembly devoted to disarmament</td>
<td>211</td>
</tr>
<tr>
<td>CCD/562</td>
<td>Sweden: terms of reference for the continued work of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events</td>
<td>212</td>
</tr>
<tr>
<td>CCD/563</td>
<td>Working paper on organization and procedures of the Conference of the Committee on Disarmament submitted by the members of the Group of 15</td>
<td>214</td>
</tr>
<tr>
<td>CCD/564</td>
<td>Union of Soviet Socialist Republics: draft decision of the Conference of the Committee on Disarmament on the establishment of an ad hoc group of qualified governmental experts to consider the question of possible areas of the development of new types and systems of weapons of mass destruction</td>
<td>216</td>
</tr>
<tr>
<td>Document No.</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>CCD/565</td>
<td>Netherlands: study on the establishment of an international disarmament agency</td>
<td>217</td>
</tr>
<tr>
<td>CCD/566 and Add.l</td>
<td>Compilation of the documents and proposals submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament which are relevant to the consideration of the comprehensive programme of disarmament</td>
<td>221</td>
</tr>
<tr>
<td>CCD/567 and Add.l</td>
<td>Tabulation of working papers and proposals on a comprehensive programme of disarmament</td>
<td>224</td>
</tr>
<tr>
<td>CCD/568</td>
<td>Italy: working paper on international mechanisms for disarmament</td>
<td>231</td>
</tr>
<tr>
<td>CCD/569</td>
<td>Sweden: working paper on a methodological investigation for computerized scanning of chemical literature</td>
<td>234</td>
</tr>
<tr>
<td>CCD/570</td>
<td>Terms of reference for the continued work of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events</td>
<td>238</td>
</tr>
<tr>
<td>CCD/571</td>
<td>Report of the Ad Hoc Working Group to Discuss and Elaborate a Comprehensive Programme for Disarmament</td>
<td>239</td>
</tr>
<tr>
<td>CCD/572</td>
<td>Terms of reference for the Ad Hoc Working Group on a Comprehensive Programme of Disarmament</td>
<td>241</td>
</tr>
<tr>
<td>CCD/573</td>
<td>Special report of the Conference of the Committee on Disarmament to the special session of the General Assembly devoted to disarmament</td>
<td>242</td>
</tr>
<tr>
<td>CCD/574</td>
<td>Schedule of meetings of the Conference of the Committee on Disarmament for the summer session</td>
<td>243</td>
</tr>
<tr>
<td>CCD/575</td>
<td>Hungary: working paper on infrasound weapons</td>
<td>245</td>
</tr>
<tr>
<td>CCD/576</td>
<td>Sixth progress report of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events</td>
<td>249</td>
</tr>
<tr>
<td>CCD/577</td>
<td>Letter dated 14 August 1978 from the Chargé d'Affaires a.i. of the Permanent Mission of Finland to the United Nations Office at Geneva addressed to the Special Representative of the Secretary-General</td>
<td>251</td>
</tr>
</tbody>
</table>
Letter dated 16 January 1978 from the Secretary-General of the United Nations to the Co-Chairman of the Conference of the Committee on Disarmament transmitting the resolutions on disarmament adopted by the General Assembly at its thirty-second session

I have the honour to transmit herewith the following resolutions adopted by the General Assembly at its thirty-second session, which entrust specific responsibilities to the Conference of the Committee on Disarmament:

32/77 - "Chemical and bacteriological (biological) weapons";

32/78 - "Urgent need for cessation of nuclear and thermonuclear tests and conclusion of a treaty designed to achieve a comprehensive test ban" and "Conclusion of a treaty on the complete and general prohibition of nuclear-weapon tests";

32/80 - "Effective measures to implement the purposes and objectives of the Disarmament Decade";

32/84 A and B - "Prohibition of the development and manufacture of new types of weapons of mass destruction and new systems of such weapons";

32/87 A - "General and complete disarmament".

I would like to draw your attention, in particular, to the following specific provisions contained in those resolutions:

(a) In resolution 32/77, operative paragraph 2 requests the Conference of the Committee on Disarmament to continue negotiations and, as a matter of high priority, to undertake the elaboration of an agreement on effective measures for the prohibition of the development, production and stockpiling of all chemical weapons and for their destruction, taking into account all existing proposals and future initiatives submitted for its consideration; and operative paragraph 5 requests the Conference of the Committee on Disarmament to report on the results of its negotiations to the General Assembly at its special session devoted to disarmament, to be held in May/June 1978, and at its thirty-third session.

(b) In resolution 32/78, operative paragraph 4 urges the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America to expedite their negotiations with a view to bringing them to a positive conclusion as soon as possible and to use their best endeavours to transmit the results for full consideration by the Conference of the
Committee on Disarmament by the beginning of its 1978 session; and operative paragraph 5 requests the Conference of the Committee on Disarmament to take up the agreed text resulting from the negotiations referred to in paragraph 4 above with the utmost urgency, with a view to the submission of a draft treaty to the General Assembly at its special session devoted to disarmament.

(c) In resolution 32/80, operative paragraph 2 requests the Conference of the Committee on Disarmament to continue its work on a comprehensive programme for disarmament and to submit a progress report to the General Assembly at its special session devoted to disarmament.

(d) In resolution 32/84 A, operative paragraph 1 requests the Conference of the Committee on Disarmament to continue negotiations, with the assistance of qualified governmental experts, aimed at working out the text of an agreement on the prohibition of the development and manufacture of new types of weapons of mass destruction and new systems of such weapons and, when necessary, specific agreements on this subject; and operative paragraph 2 requests the Conference of the Committee on Disarmament to submit a report on the results achieved to the General Assembly for consideration at its thirty-third session.

(e) In resolution 32/84 B, operative paragraph 5 requests the Conference of the Committee on Disarmament, while taking into account its existing priorities, to keep under review the question of the development of new weapons of mass destruction based on new scientific principles and to consider the desirability of formulating agreements on the prohibition of any specific new weapons which may be identified; and operative paragraph 6 requests the Conference of the Committee on Disarmament to report on its review to the General Assembly at its thirty-third session.

(f) In resolution 32/87 A, operative paragraph 4 requests the Conference of the Committee on Disarmament - in consultation with the States parties to the Treaty and taking into account the proposals made during the Review Conference and any relevant technological developments - to proceed promptly with the consideration of further measures in the field of disarmament for the prevention of an arms race in that environment; and operative paragraph 7 requests the Conference of the Committee on Disarmament to report on its negotiations to the General Assembly at its thirty-third session.

The General Assembly, in the above-mentioned resolutions 32/77, 32/80, 32/84 A and 32/87 A, also requested the Secretary-General to transmit to the Conference of the Committee on Disarmament all the relevant documents and records. They are the following:

The relevant documents and records in connexion with resolution 32/78 are the following:


All these documents and records were distributed during the thirty-second session of the General Assembly to all Members of the United Nations, including all Members of the Conference of the Committee on Disarmament.

I also have the honour to transmit herewith, for the information of the Conference of the Committee on Disarmament, the following resolutions adopted by the General Assembly at its thirty-second session which deal with disarmament matters:

32/75 - "Economic and social consequences of the armaments race and its extremely harmful effects on world peace and security".

32/76 - "Implementation of General Assembly resolution 31/73 (XXX) concerning the signature and ratification of Additional Protocol I of the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco)".

32/79 - "Implementation of General Assembly resolution 31/67 concerning the signature and ratification of Additional Protocol II of the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco)".

32/81 - "Implementation of the Declaration on the Denuclearization of Africa".

32/82 - "Establishment of a nuclear-weapon-free zone in the region of the Middle East".

32/83 - "Establishment of a nuclear-weapon-free zone in South Asia".

32/85 - "Reduction of military budgets".

32/86 - "Implementation of the Declaration of the Indian Ocean as a Zone of Peace".

32/87 B to G - "General and complete disarmament".

32/88 A and B - "Special session of the General Assembly devoted to disarmament".

32/89 - "World disarmament conference".

32/152 - "Incendiary and other specific conventional weapons which may be the subject of prohibitions or restrictions of use for humanitarian reasons".

-3-
I also wish to call attention to the following resolutions which are related to disarmament matters:

- **32/44** - "Respect for human rights in armed conflicts".
- **32/49** - "Report of the International Atomic Energy Agency".
- **32/50** - "Peaceful use of nuclear energy for economic and social development".
- **32/150** - "Conclusion of a world treaty on the non-use of force in international relations".
- **32/154** - "Implementation of the Declaration on the Strengthening of International Security".
- **32/155** - "Declaration on the deepening and consolidation of international détente".

In addition, I would like to recall that in resolution **32/88 B**, the General Assembly endorsed the report of the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament (A/32/41) and the recommendations contained therein. Among them is a request to the Conference of the Committee on Disarmament to submit to the General Assembly at its special session devoted to disarmament a special report on the state of the various questions under consideration by the Conference.

Accept, Sir, the assurances of my highest consideration.

(Signed) Kurt Waldheim
Secretary-General

For the text of the above-mentioned resolutions, see Official Records of the General Assembly, Thirty-second Session, Supplement No. 45.7
ITALY

Working paper on the question of the drafting of a comprehensive programme of disarmament

I. GENERAL OBJECTIVES AND PRINCIPLES

The ultimate goal of disarmament negotiations is general and complete disarmament under strict and effective international control.

In view of the achievement of this final objective agreement should be reached on a comprehensive and phased negotiating programme, dealing with all aspects of the cessation of the arms race and disarmament.

A global programme for disarmament should be based - inter alia - on the following general considerations and principles:

1. Negotiations on disarmament are essential for peace and have widespread repercussions. Although they may be influenced by international events, they cannot fail to constitute a dynamic and positive factor in the evolution of the political situation as a whole.

2. The great majority of States have expressed their determination to proceed along the twin paths of general and complete disarmament and adoption of specific measures. The two issues are closely linked, and the aim of future negotiations should be to combine them harmoniously.

3. As all nations have a vital interest in the outcome of disarmament negotiations, disarmament efforts should be granted the active participation and the support of all States, and particularly of nuclear-weapon States and other military significant States, which bear, in the disarmament process, a special responsibility.

4. Through efforts which have been continuing for over a quarter of a century, the United Nations and the Conference of the Committee on Disarmament have definitely made some progress in the disarmament field by establishing specific agreements and by adopting an important series of principles which form, so to speak, the "charter" of disarmament: for example, the principles approved on 20 December 1961 and adopted by the General Assembly in resolution 1722 (XVI).

5. In order to prevent the disarmament process from creating imbalances or strengthening positions of privilege, it will be necessary to adopt collective security measures and to carry out the most effective and appropriate verifications.

-5-
Any programme of negotiations on disarmament should be coherently and globally planned, and should be so conceived as to provide the international community with clear guidelines. The disarmament process will then be able to follow a rational course from its initial or priority stages to its final culmination: general and complete disarmament under effective international control. Such disarmament should be accompanied by the establishment of reliable procedures for the peaceful settlement of disputes and effective arrangements for the maintenance of peace and security in accordance with the principles of the United Nations Charter.

To achieve wide acceptance, the comprehensive programme envisaged should attempt to identify priorities and strike a balance among its various components and objectives, seeking its implementation in successive stages but without rigid time-limits.

Specifically, this programme would embody the following elements:

(a) a degree of flexibility in following the time-table set forth;

(b) a balance between the measures to be taken in the various fields of disarmament - thus nuclear disarmament would parallel conventional disarmament - in order to guarantee undiminished security to all States;

(c) an appropriate co-ordination of global and regional disarmament.

While pursuing the adoption of a comprehensive disarmament programme, negotiations should be carried out with new impetus and perseverance with the immediate objective of halting and then reversing the arms race by means of specific measures affecting both nuclear and conventional arsenals.

Such measures should aim to facilitate the achievement of the final goal of a general and complete disarmament plan and would constitute an integral part of it.

Effective verification methods form an essential part of disarmament measures. A combination of several verification techniques should be applied whenever necessary, including those international means of inspection and control which would appear appropriate to ascertain that agreed disarmament obligations are being fully complied with by all Parties thereto.

Measures for curbing the arms race and promoting disarmament should not prejudice the inalienable right of all States freely to accede to peaceful applications of scientific and technological discoveries.

II. MAIN ELEMENTS OF THE DISARMAMENT PROGRAMME

The following main elements should be included in a comprehensive programme for action in the disarmament field:

(A) Nuclear weapons and other weapons of mass destruction;

(B) Conventional weapons;

(C) Other measures.
(A) (1) NUCLEAR WEAPONS, INCLUDING NON-PROLIFERATION

(a) Conclusion, as a measure of the highest priority, of a comprehensive nuclear test ban (CTB)

To this effect ongoing tripartite consultations between the United States of America, USSR and the United Kingdom should be speeded up in order to make it possible for the CCD to achieve at an early date a widely acceptable treaty. All nuclear weapon States should be urged to join in these negotiations as soon as possible.

(b) Limitation and reduction of nuclear weapons and delivery systems

It is necessary for the nuclear Powers to halt and then reverse the arms race. To this end vigorous efforts should be made to expedite the SALT negotiations.

Eventual elimination of all nuclear weapons in the context of general and complete disarmament is the most important challenge of our time since the dangers of nuclear warfare remain a grave threat of the very survival of mankind.

(c) Cessation of the production of fissionable materials for military purposes

(d) Strengthening of the non-proliferation régime

Universal adherence to the NPT should be actively encouraged. All States should be urged to ratify the Treaty or at least to abide by its provisions and objectives. Parallel efforts should be undertaken by nuclear weapon States with the view of honouring their obligations under article VI of the Treaty. Substantive and timely measures should be devised in order to guarantee to all States — as provided by article IV — the exercise of their inalienable right to develop — under appropriate internationally agreed safeguards and through increased international co-operation — research, production and use of nuclear energy for peaceful purposes and to enjoy the benefits thereof.

(e) Nuclear-weapons-free zones

Nuclear-weapons-free zones should be viewed both as a useful complementary instrument of the non-proliferation régime and as an effective disarmament measure. Their establishment, when suitable conditions exist, should originate from the States directly concerned, on a voluntary and regional basis, and with the participation of all militarily significant States of the area.

(A) (2) OTHER WEAPONS OF MASS DESTRUCTION

(a) Early conclusion of an international convention on the prohibition of the development, production and stockpiling of all chemical weapons and of their destruction is a most urgent feature. The two major military Powers should engage in decisive efforts in view of finalizing their announced joint initiative. Simultaneously the CCD should materialize through concrete steps its commitment to the total elimination of chemical warfare agents.

(b) Efforts should be made by the CCD to reach agreement on a treaty prohibiting the development, stockpiling and use of radio-active material weapons
("radiological weapons") as defined in the resolution dated August 1948 of the United Nations Commission for Conventional Armaments.

(c) Efforts should be made to avoid the development of new weapons of mass destruction based on new scientific principles. The CCD should keep this question under review and consider the desirability of formulating agreements on the prohibition of any specific weapon which may be identified.

(B) CONVENTIONAL WEAPONS

(a) Limitation and reduction of conventional weapons and armed forces should be negotiated in parallel with nuclear disarmament progress as a part of a balanced comprehensive programme. New approaches for successful developments in this field should be sought, when appropriate, on a regional basis.

(b) Restraints on the transfer of conventional arms should proceed simultaneously with the limitation of arms and armed forces levels. In this respect, the establishment, on the basis of Article 29 of the Charter of the United Nations, of a Commission divided into regional sub-commissions in which the main arms suppliers of each region would participate, should be envisaged, in view of keeping conventional armaments at the lowest possible level. To facilitate the setting up of the above-mentioned regional subsidiary organs with the consent of the parties concerned, the establishment of committees or separate parallel group in which the purchasing countries would participate might prove advisable.

(c) States should seek agreement, on the basis of consensus, on the prohibition or limitation of use of certain specific conventional weapons.

(C) OTHER MEASURES

(a) Conduct of pilot studies by a group of States on a voluntary and reciprocal basis, for the purpose of devising and testing jointly an effective international system of reporting for the military expenditure with the object of reducing military budgets. Reduction of military budgets in all countries on an assured basis could provide undiminished security at a lower level of armaments, help to reduce international tensions and also lead eventually to the release of resources both nationally and internationally for economic and social development of mankind.

(b) Publication by all States of more information about their armed forces and in particular about any kind of expenditure devoted to military purposes and a mechanism should be established under the United Nations auspices to collect such information.

(c) Publication by the United Nations of all available data on the production and transfer of weapons and the development of an effective system for processing such data.

(d) Preparatory studies on the conversion of the armaments industries of the principal developed countries should be initiated with the aim of providing alternative lines of production, while maintaining the employment rate at a constant level.
(e) A United Nations expert study on the relationship between disarmament and development should be initiated as soon as possible after the special session.

(f) The CCD should proceed, in consultation with the States party to the Sea-bed Treaty, to the consideration of further measures in the field of disarmament for the prevention of the arms race on the sea-bed and the ocean floor and the subsoil thereof. Parallel efforts should be made for the Outer Space in accordance with the spirit of the 1967 Treaty.

(g) Specific measures to establish an international climate of confidence (CBM).

III. STRENGTHENING INTERNATIONAL PEACE AND SECURITY

The process towards GCD under strict and effective international control should be accompanied by the establishment of reliable procedures for the peaceful settlement of disputes and in accordance with the United Nations Charter effective arrangements for the maintenance of peace and security, including renewed efforts to supplement by means of appropriate guidelines the arrangements concerning the United Nations peace-keeping operations. Studies and/or negotiations should be undertaken with a view to recruiting a permanent United Nations police force (Art. 43 of the Charter) and establishing an international organ to supervise the application of disarmament agreements in force.

General and complete disarmament under strict and effective international control shall permit States to have at their disposal only those non-nuclear forces, armaments, facilities and establishments as are agreed to be necessary to maintain internal order and protect the personal security of citizens and in order that States shall support and provide agreed manpower for a United Nations police force.
CANADA, GERMANY, FEDERAL REPUBLIC OF, ITALY, JAPAN, NETHERLANDS AND UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Draft programme of action for the special session of the General Assembly devoted to disarmament

I. GENERAL

The States Members of the United Nations at the eighth special session of the General Assembly solemnly affirm that their ultimate goal is general and complete disarmament under strict and effective international control. They recognize that this goal requires an increase in international confidence and security to remove the incentive for States to acquire weapons and to encourage them to reduce these from present levels. The States Members therefore believe that a serious world-wide disarmament strategy must be accompanied by a greater and sustained effort to eliminate the sources of tension and injustice in the world and to increase the effectiveness of international machinery in the United Nations and elsewhere for the peaceful settlement of disputes: to uphold the international rule of law: and to promote the political, civil, social and economic rights of man. This strategy should take into account not only the quantitative but also the qualitative aspect of disarmament, and should result in the release of resources for the satisfaction of the economic and social needs of humanity particularly in the developing countries.

This programme of action sets out in chapter II priority negotiations for completion over the next few years. In addition it proposes concurrent measures and studies to prepare the way for future negotiations and for progress towards general and complete disarmament. It gives practical effect to the principles set down in the Declaration on Disarmament. A prerequisite for a successful disarmament strategy is the adherence of all States to existing arms control and disarmament agreements.

II. IMMEDIATE MEASURES OF ARMS CONTROL AND DISARMAMENT

1. In the nuclear field, in which the Nuclear Weapon States have a particular responsibility, the realization of the central objectives of preventing both horizontal and vertical proliferation by:

   - the halting and the reversal of the nuclear arms race in its quantitative and qualitative dimensions: especially by a second Strategic Arms Limitation Agreement between the United States and the Soviet Union, to be followed urgently by further strategic arms negotiations with the objective of reducing and eventually eliminating nuclear weapons.

the earliest conclusion of a Comprehensive Test Ban Treaty banning all nuclear explosions in all environments, which should be adhered to as soon as possible by all States, particularly all Nuclear Weapon States and should contain verification provisions giving maximum confidence that no party would conduct clandestine tests.

- further measures to develop an international consensus on the strengthening and consolidation of the nuclear non-proliferation régime, based primarily on adherence of all States to the Non-Proliferation Treaty and on the system of safeguards of the IAEA. Measures to be pursued should include assistance to the IAEA in its attempts to strengthen its safeguards systems: the application of IAEA safeguards on all source and special fissionable material in all peaceful nuclear activities: agreement on adequate standards for the physical protection of nuclear materials: study and possible development of alternative and more proliferation-resistant nuclear technologies: an examination of the possibility of giving a suitable international character to appropriate nuclear fuel cycle operations, and to effective measures for the control of plutonium in civil nuclear programmes: and support for the work currently being undertaken in the International Nuclear Fuel Cycle Evaluation. These measures should be designed to facilitate international access to the use of nuclear technology for peaceful purposes and take account of the particular needs of the developing countries in this area, as well as to prevent the proliferation of nuclear weapons.

- the establishment of additional nuclear weapon free zones suitable to specific conditions in the regions concerned through agreement between all the States in the region and with effective co-operation from Nuclear Weapon States.

2. Assurances, as appropriate, by Nuclear Weapon States designed to increase the confidence of Non-Nuclear Weapon States in their own security from nuclear attack.

3. Other weapons of mass destruction:

- a convention prohibiting the development, production and stockpiling of chemical weapons and regulating their destruction.

- a convention prohibiting the development, production, stockpiling and use of radiological weapons.

- continuing review of the question of new weapons of mass destruction based on new scientific principles with a view to consideration of agreements on the prohibition of any new weapons which may be identified.

4. Conventional weapons and armed forces:

- agreements or other measures on a bilateral, regional and multilateral basis for placing restrictions on the production, transfer and acquisition of conventional weapons.

- conventions prohibiting or limiting the future use in armed conflict of certain conventional weapons which may be indiscriminate in their effects or may cause unnecessary suffering.

- agreements or other measures on a regional basis, aiming at strengthening peace and security, in particular urgent efforts to contribute to a more stable military relationship in Europe.
5. The measures listed above should form part of a balanced programme of disarmament and provide for adequate verification including, if appropriate, the possibility of on-site inspection. Verification provisions should be so designed as to ensure the effectiveness of agreements and to enhance mutual confidence.

III. THE FURTHER STRENGTHENING OF INTERNATIONAL SECURITY AND CONFIDENCE

In addition to undertaking the specific arms control and disarmament tasks described above, the States members of the United Nations, in order to strengthen international confidence and deepen the dialogue between those involved in defence matters in different countries, should:

1. Support the Secretary-General in his efforts further to strengthen the expertise and capability of the United Nations to play its essential role as a catalyst in the disarmament process.

2. Encourage the further discussion and development by the CCD of a comprehensive programme for disarmament.

3. Publish detailed information about their armed forces, and the total value of their arms production and of their transfers of arms to other countries.

4. Supply full information on military budgets using the method shortly to be finalized through a pilot study by the Secretary-General for the standardized reporting of such budgets as a step toward verified and balanced reductions in military expenditure.

5. Assess the possible implications of military research and development for existing agreements as well as for further efforts in the field of arms control and disarmament.

6. Seek to restrain the world-wide build-up of conventional weapons, utilizing all means which could lead to bilateral, regional and multilateral measures of control, limitation and balanced reduction of such armaments.

7. Accept adequate provisions of international control as appropriate to facilitate the conclusion and effectiveness of disarmament agreements.

8. Stimulate public awareness of disarmament issues by:
   - publicizing the final documents of the special session, in particular through non-governmental organizations, mass media and educational systems.
   - facilitating public access to information on disarmament questions.
   - improving mechanisms for the dissemination of relevant United Nations publications and
   - encouraging study and research on disarmament.
9. Take the following actions to increase confidence between States bilaterally, regionally or world-wide:

- to inform States, on a regional basis, and in accordance with regionally established criteria, 21 days or more in advance about their intention to carry out major military movements or manoeuvres.

- to invite observers from States on a regional basis to manoeuvres and encourage military visits and exchanges of all kinds on a reciprocal basis.

- to improve communications between Governments, particularly in areas of tension, by the establishment of "hot lines" and other methods of reducing the risk of conflict due to misunderstanding or miscalculation.

IV. STUDIES TO FACILITATE FURTHER MEASURES

In order to facilitate further steps in disarmament and parallel measures to promote international peace and security, the Secretary-General is requested to carry out studies relating to:

1. The strengthening of the security role of the United Nations in peacekeeping and the peaceful settlement of disputes to enable it to anticipate and resolve international crises.

2. Ways of limiting the build-up of conventional weapons, regionally and throughout the world, taking into account all relevant aspects, inter alia:

- the international transfer of conventional weapons,

- the possibility of reciprocal limitation of the level and types of conventional weapons.

- the proposal for a United Nations Register of Weapons Transfers.

3. The relationship between disarmament and development to be initiated as soon as possible after the special session. The terms of reference of this study should be on the basis of the report of the ad hoc group of governmental experts.

4. All regional aspects of disarmament, including further measures designed to increase confidence and stability as well as means of promoting disarmament on a regional basis.

5. The possible contribution to confidence-building among States of technical measures such as demilitarized zones, zones of limited forces and surveillance and early warning systems which could be used as appropriate in areas of tension: and on the use of some of these measures in the verification of arms control agreements.

V. IMPLEMENTATION

All States undertake to work towards the fulfilment of this programme, and to respect agreed measures relating to it. The General Assembly should examine its implementation, as appropriate, taking account of the recommendations on disarmament machinery made later in the final document.
ARGENTINA, EGYPT, ETHIOPIA, INDIA, PERU, YUGOSLAVIA
AND ZAIRE

Special session of the General Assembly devoted to disarmament:
non-aligned working document containing the draft declaration,
programme of action and machinery for implementation
(A/AC.187/55/Add.1)

For the text of document A/AC.187/55/Add.1, see Official Records of the
General Assembly, Tenth Special Session, Supplement No. 1, vol. IV.

Schedule of meetings of the Conference of the Committee on Disarmament for the spring session

(Adopted at the 772nd plenary meeting on 16 February 1978)

Plenary meetings

Plenary meetings will continue to be held on Tuesday and Thursday at 10.30 a.m., unless decided otherwise. The agenda for the plenary meetings, adopted on 15 August 1968, reads as follows:

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

"Under this heading members may wish to discuss measures dealing with the cessation of testing, the non-use of nuclear weapons, the cessation of production of fissionable materials for weapons use, the cessation of manufacture of weapons and reduction and subsequent elimination of nuclear stockpiles, nuclear-free zones, etc.

"2. Non-nuclear measures.

"Under this heading, members may wish to discuss chemical and bacteriological warfare, regional arms limitations, etc.

"3. Other collateral measures.

"Under this heading, members may wish to discuss prevention of an arms race on the seabed, etc.

"4. General and complete disarmament under strict and effective international control.

"The Co-Chairmen note the recognized right of any delegation to raise and discuss any disarmament subject in any meeting of the Committee."

Further, pursuant to the decision of 29 April 1977, as well as the relevant discussions of this decision in the Committee, it is noted that the Committee can establish an ad hoc working group whenever it deems it appropriate to do so under the procedural decision of 21 April. It is noted that on 25 August 1977 the Committee agreed that, at the beginning of the 1978 Spring Session, an ad hoc working group would be established to discuss and elaborate a draft comprehensive programme of disarmament to be submitted to the CCD for consideration.
Informal meetings of the CCD

31 January-17 February  - Informal meetings of CCD, as required, to discuss the CCD Spring Session schedule of work.

20-24 February  - Informal meetings of CCD to discuss the terms of reference for the Working Group on Comprehensive Programme of Disarmament.

27 February-3 March* - Informal meetings of CCD on the Committee's organization and procedures, including consideration of the preparation of the Special Report to be submitted to the Special Session of the United Nations General Assembly Devoted to Disarmament.

6-10 March* - OPEN

13-17 March - Informal meetings of CCD to consider the Final Report of the Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events. Informal meetings of CCD on a comprehensive nuclear test ban.

20-24 March - OPEN

28-31 March - Informal meetings of CCD, with participation of experts, on new types and systems of weapons of mass destruction.

3-7 April - Informal meetings of CCD, with participation of experts, on chemical weapons.

10-14 April - Informal meetings of CCD to consider the draft special report to SSOD on state of various questions under consideration by CCD.**

END OF SPRING SESSION***

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* During the period from 27 February to 10 March, the Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events will hold its Final Session.

** In case the Spring Session ends after 14 April this consideration will take place during the last week of the session.

*** The Committee will decide subsequently on when the Spring Session will end, and on the question of a brief recess in April.
I. Fundamental purposes and principles

The following fundamental purposes and principles should constitute the basis for negotiations and decisions on questions of curbing the arms race and achieving disarmament.

1. The relaxation of international tension and related positive political processes can become truly established if they are accompanied and strengthened by measures of military détente, i.e. by new tangible results in the field of limiting the arms race and of disarmament.

2. The principal and ultimate objective of the efforts of States in this field is general and complete disarmament under strict international control; only general and complete disarmament can bring mankind, on a firm and long-term basis, the universal peace and security which are essential in order to solve urgent problems of economic and social development on a world-wide scale.

3. Specific partial measures aimed at limiting the arms race, reducing armaments and achieving disarmament can play an important role as stages on the road to general and complete disarmament and the establishment of a stable peace. Such partial measures should entail the prohibition and destruction of certain types of existing armaments, prevention of the development of new types and systems of weapons of mass destruction, the exclusion of certain spheres or regions of the world from the arms race, the systematic reduction of the military expenditures of States, the limitation of armaments and the achievement of disarmament on a regional basis, as well as other steps to prepare the way for general and complete disarmament.

All States should refrain from actions which might adversely affect efforts in the field of disarmament. An important prerequisite for the success of negotiations on limiting armaments and achieving disarmament is the willingness of States to adopt a constructive approach to negotiations and to demonstrate the political will to reach agreements.

4. Measures to curb the arms race and bring about disarmament should be based on the principle of not impairing the interests of any of the parties to an agreement; strict adherence to this principle and abandonment of attempts to obtain unilateral advantages are the essential prerequisites for the effectiveness of negotiations and the viability of agreements once they have been worked out.
5. The universal affirmation and development of the principle of the non-use of force in international relations are extremely important in terms of ensuring favourable conditions for curbing the arms race and saving mankind from the danger of war. Renunciation of the use or threat of force must become a law of international life.

6. In order to prevent the continuation of the arms race it is essential to put an end to qualitative improvements of arms, especially weapons of mass destruction, and to the development of new means of warfare. Scientific and technological achievements must be used solely for peaceful purposes.

7. If disarmament measures are to be effective, it is of the utmost importance that negotiations and agreements should involve the largest possible number of States, particularly the nuclear Powers and States which possess the most powerful weapons and armed forces. The participation of all the nuclear Powers in efforts to curb the nuclear arms race and to limit and eliminate all armaments is essential if complete success is to be achieved in this regard. The accession of all States to existing international agreements aimed at limiting the arms race and achieving disarmament is a major prerequisite for further progress in this field. A world disarmament conference must be used as an important forum for working out specific and effective measures to solve the problem of disarmament.

8. Agreements in the field of disarmament must provide for effective verification of disarmament measures, with the scope and nature of such verification depending on the scope, nature and specific characteristics of the specific measures provided for in the agreements.

9. The resources released as a result of the implementation of disarmament measures should be used in a manner which will promote the well-being of peoples, the solution of world-wide problems faced by mankind, and the economic and social progress of the developing States.

II. Basic provisions

In accordance with the above purposes and principles, it is essential to seek appropriate international agreements in the following principal areas:

Cessation of the nuclear arms race and nuclear disarmament. Agreement must be reached on the simultaneous cessation of the production of nuclear weapons by all States. This would apply to any such weapons - whether atomic, hydrogen or neutron bombs or projectiles. At the same time, the nuclear Powers could undertake to make a start on the gradual reduction of existing stockpiles of such weapons, and move towards their complete, total destruction.

Measures to avert the danger of nuclear war. Measures to avert the danger of nuclear war should be taken in the interest of achieving disarmament and providing reliable safeguards for the future of all mankind. Such measures can be bilateral and multilateral.

Complete and general prohibition of nuclear-weapon tests. This urgent measure, for the implementation of which all the necessary prerequisites exist,
including the solution of the problem of effective verification of compliance, will make it possible to put an end to the qualitative improvement of nuclear weapons and to prevent the development of new types of such weapons.

Consolidation in every possible way of the régime of the non-proliferation of nuclear weapons. The Treaty on the Non-Proliferation of Nuclear Weapons should be made more effective and truly universal; the IAEA system of safeguards should be strengthened in every possible way; broad international co-operation in the peaceful uses of nuclear energy, which plays an important role in the development of the national economies of States, should not be permitted to become a channel for the proliferation of nuclear weapons and other nuclear explosive devices.

Prohibition of the development, production and stockpiling of chemical weapons and destruction of stocks of such weapons. The elimination of this type of weapons of mass destruction is long overdue. This problem should be solved radically and by a single action, as was the case with bacteriological weapons. There is not, and there cannot be, any reason for delay on the question of banning chemical weapons. What is needed is a demonstration of the political will and desire to reach generally-acceptable agreement.

Prohibition of the development of new types and systems of weapons of mass destruction. The solution of this problem is very urgently needed as a means of curbing the most dangerous aspects of a continued arms race and preventing the use of scientific and technological achievements for the destruction of human beings.

Establishment of nuclear-free zones and zones of peace. The establishment of nuclear-free zones and zones of peace in various parts of the world is an important measure of regional military détente; it should contribute to strengthening the security of States within such zones and international security as a whole. Specifically, it would be of great importance to establish a zone of peace in the Indian Ocean, to withdraw ships and submarines carrying nuclear weapons from the Mediterranean area, and to establish nuclear-free zones in various parts of the world.

Limitation and reduction of armed forces and conventional weapons. Military conflicts involving the use of conventional weapons lead to the tragic and often mass destruction of human lives and of the material values created by man. Accordingly, practical steps should be taken to limit and reduce the number of aircraft, artillery pieces, tanks and other modern types of conventional weapons, as well as the armed forces equipped with such weapons. Foreign military bases in foreign territories should be eliminated; foreign troops should be withdrawn from such territories.

Reduction of military budgets. This measure is one of the most effective means of curbing the arms race. The resources thus released would be used to promote the economic and social progress of peoples and to provide assistance to developing countries. The question of reducing military appropriations should be made the subject of specific, businesslike negotiations among States, and a start should be made on their systematic reduction.

Complete demilitarization of the sea-bed and the ocean floor. The exclusively peaceful use of the sea-bed and the ocean floor should be the ultimate goal of States in this field. A major contribution could be made to the
achievement of this goal if all the parties to the Treaty on the Prohibition of
the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the
Sea-Bed and the Ocean Floor and in the Subsoil Thereof complied strictly with
their obligations, if the number of parties to this Treaty was increased and if a
new agreement on complete demilitarization of the sea-bed was worked out as soon
as possible.

Regional measures for military détente and disarmament. Measures such as
mutual reductions of armed forces together with the establishment of zones of
peace and nuclear-free zones can make a substantial contribution to the limitation
of the arms race and to disarmament, above all in those areas where military
confrontation is particularly serious.

III. Machinery for disarmament negotiations

All channels for the conduct of negotiations should be effectively used by
the States of the world for the solution of vital problems connected with the
ending of the arms race and achieving disarmament.

On the whole, the existing system of negotiations - multilateral, bilateral
and regional - is suited to the scope and nature of the varied problems of
disarmament. The existing types of negotiations should continue to be used in
order to reach the necessary international agreements.

A breakthrough in solving the disarmament problem, which affects the
interests of all countries without exception, requires that it should be
considered in the broadest and most authoritative international forum - a World
Disarmament Conference. Such a truly universal forum could, with expertise and
in sufficient depth, consider the entire range of disarmament questions. If
properly organized and with working bodies available to ensure thorough
preparation of and practical agreement on appropriate decisions with due regard for
the interests of all States, a World Disarmament Conference could work out specific,
effective measures aimed at curbing the arms race and achieving disarmament.

The United Nations General Assembly special session on disarmament should
become an important international forum for a broad discussion of approaches of
principle to the solution of disarmament questions as well as of the main areas in
which priority efforts should be made by States in this sphere. The convening of
the special session and its decisions should contribute to the work of existing
forums of disarmament negotiations which are responsible for the elaboration of
practical steps and agreements aimed at ending the arms race and achieving
disarmament.
Working paper on the draft comprehensive programme of disarmament

1. The need for a comprehensive Programme of Disarmament has evolved together with the increasing awareness that disarmament is a matter of universal concern and consequently it requires intensive and well organized efforts by all States.

Past experiences in the field of disarmament negotiations have also demonstrated that measures, conceived separately and unco-ordinated within a global perspective did not suffice to launch the process of a real disarmament, and had no practical effect on the dynamics of the arms race which continued unhindered and failed to mobilize the world-wide efforts towards disarmament.

2. The aim of the elaboration of a global programme for disarmament is to set in motion a guideline to chart the negotiations in this field so that the disarmament process could follow a rational course according to established objectives. It should provide the Special Session of the General Assembly on Disarmament with a long-term perspective of the basic objectives to which the political will of States has to be mobilized.

So conceived, a Comprehensive Programme of Disarmament should answer the following three basic requirements:

(a) it should establish a unified concept for the organization of the negotiations in the field of disarmament;

(b) it should provide a system of disarmament measures, organically subordinated to the ultimate goal which is general and complete disarmament, thus integrating and co-ordinating the negotiations in a world-wide disarmament strategy. The negotiations should be carried on concurrently on several measures so that the efforts so organized could influence and support each other and open the way for further steps.

To that end absolute priority should be given to nuclear armaments given the grave danger they present for humanity and their impact for the acceleration of the arms race in other fields;

(c) it should be comprehensive, e.g. it should deal with all aspects of the problem of disarmament. Therefore the programme should provide, along with the measures aimed at achieving the ultimate goal of general and complete disarmament, intermediary steps, such as confidence building, collateral and partial measures.

As to its scope, the negotiating programme should stimulate the universal and the regional as well as the bilateral efforts, all of them incorporated in the requisite global planning of the agreed objectives.
3. The arms race carries with it the germ of the disruption of the military balance. A primary purpose of the Comprehensive Disarmament Programme should be, therefore, the planning of the efforts aimed at preserving security and the military balance not through an increase in armaments but through their reduction. Consequently, the programme should aim at crossing the line from preventive and arms control measures to real disarmament measures.

This implies, among others, that the basic factor in the elaboration of the Comprehensive Disarmament Programme is the political will of States.

Elements for a Comprehensive Programme of Disarmament

1. Negotiation and conclusion of the Treaty on general and complete disarmament.

Negotiations on this item should be resumed and carried on without interruption concurrently with the negotiations on any collateral or partial measures, with the participation of all States, in all phases of the drafting of the clauses of the Treaty. They will provide the necessary impact on all other negotiations by constantly focussing the attention on the global framework to which all such parallel efforts are confined.

2. Cessation of the nuclear arms race and nuclear disarmament.

(a) solemn undertaking by the nuclear weapon States not to be the first to use the nuclear weapon;

(b) solemn undertaking by the nuclear weapon States not to use or threaten to use nuclear weapons against non-nuclear weapon States at any time and under any circumstances;

(c) prohibition of the deployment of new nuclear weapons on the territory of other States; total prohibition of the deployment of nuclear weapons on the seabed and ocean floor and in the subsoil thereof;

(d) withdrawal of nuclear weapons from the territory of other States;

(e) cessation of the development and testing of nuclear weapons and their means of delivery (including the comprehensive test ban of nuclear weapons);

(f) cessation of the production of fissionable materials for military purposes; conversion of existing materials to peaceful purposes and transfer of a quota of such materials to be used by all States in the framework of a broad international co-operation;

(g) setting up of nuclear-weapon-free zones of peace and co-operation in various regions of the world accompanied by effective guarantees by nuclear weapon States to observe their status;

(h) reduction and complete destruction of all stockpiles of nuclear weapons and of their means of delivery;

(i) complete prohibition of nuclear weapons.
During the negotiations on these measures the legitimate rights of all States should be fully observed to peaceful uses of nuclear energy on an equal basis and without any discrimination.

3. **Prohibition of other weapons of mass destruction.**

   (a) prohibition of the research and manufacture of new types of weapons of mass destruction and new systems of such weapons;

   (b) prohibition of the use, cessation of the production and destruction of the existing stockpiles and outlawing of all weapons of mass destruction (chemical, bacteriological or any other type);

   (c) complete prohibition of the use of environmental modification techniques for military or any other hostile purposes.

4. **Collateral measures of disarmament and military disengagement.**

   (a) freezing and gradual reduction of military budgets starting with the budgets of the major, heavily armed Powers; setting up of a programme for progressive reduction of military budgets;

   (b) withdrawal within their national frontiers of foreign troops, their armaments and other combat equipment and demobilization of the withdrawn troops;

   (c) dismantling of military bases on foreign territories.

5. **Confidence building measures.**

   (a) discontinuance of military manoeuvres, particularly those of multinational nature, near the frontiers or on the territory of other States; prohibition of concentration of troops as well as of demonstrations of force directed against other States; conclusion of international agreements in this field starting in Europe;

   (b) prevention of military attacks due to accidents, miscalculation or communication failure; conclusion of international agreements in this field;

   (c) measures to reduce military activities on the ground, in the air and on the sea and oceans; complete prohibition of the use of the seabed and ocean floor and of the subsoil thereof for military purposes;

   (d) undertaking by all States to ban all forms of war propaganda and hatred among nations;

   (e) dissolution of military blocs.

6. **Reduction of conventional armaments and armed forces and their gradual elimination.**

   This objective should be conceived as the final stage of the goal of general and complete disarmament.

   (a) gradual reduction of conventional armaments and national armed forces; conclusion of international agreements to ensure the effective implementation of all measures adopted in this respect;

   (b) quantitative and qualitative ceilings of national armed forces and military equipment.
SWEDEN

Elements for inclusion in the programme of action of the special session of the General Assembly devoted to disarmament and in its documents relating to the machinery for disarmament negotiations (A/AC.187/95)

For the text of document A/AC.187/95, see Official Records of the General Assembly, Tenth Special Session, Supplement No. 1, vol. VI.
Suggestions for inclusion in a comprehensive programme of disarmament

1. In declaring the 1970s as a Disarmament Decade the United Nations General Assembly in the relevant resolution 2602 E (XXIV) of 16 December 1969 directed the Conference of the "Committee on Disarmament while continuing intensive negotiations with a view to reaching the widest possible agreement on collateral measures, to work out at the same time a comprehensive programme dealing with all aspects of the problem of the cessation of the arms race and general and complete disarmament under effective international control which would provide the Conference with a guideline to chart the course of its further work and its negotiations". The time lapse between the adoption of that resolution and today has served to further strengthen the need for such a Comprehensive Programme which is now universally recognized as an essential element in the disarmament process.

2. Negotiations in the CCD itself have been taken up in a rather haphazard manner depending mainly on the convenience of the Co-Chairmen or their perspective of what is ripe for consideration. Negotiations have also been taken up outside the CCD on issues of interest but with very little co-ordination with either the CCD or the United Nations. While it is recognized that the multifora approach to disarmament is useful and perhaps inevitable, it is essential to ensure the interrelationship of these efforts and their co-ordination so as to facilitate periodic review of over-all progress.

3. Thus the aim of a Comprehensive Programme of Disarmament will have to be broadened beyond the original perspective of the General Assembly in resolution 2602 E (XXIV). Such a Programme should form a reference point not only for the CCD but for disarmament negotiations conducted in all other fora, so that taken together, these negotiations form a co-ordinated effort that will permit discernible progress in the over-all objective of general and complete disarmament.

Aim and objective

4. The ultimate objective of disarmament negotiations is the attainment of general and complete disarmament which will facilitate conditions of peace, security and a new international economic order.

5. To this end a Comprehensive Programme of Disarmament should aim at providing negotiators, at whatever forum, with an orderly, well balanced programme complete with a system of priorities and co-ordination that will ensure discernible and constant progress towards general and complete disarmament under effective international control.
Principles

6. (a) In formulating the principles that should govern disarmament negotiations it should be borne in mind that disarmament constitutes a vital means to an end. It is an important corner-stone of a new international peace and security order which will combine the world wide relief from the present nuclear over-kill capacity with an acceptable economic and social condition of living for all peoples. Until genuine disarmament is achieved, it is clear that world economic and social progress cannot run its full course.

(b) Disarmament is in the basic interest of all States both in its aspect as a *sine qua non* to international peace and security and as a necessary input into the economic and social development of all States particularly the developing countries. Thus negotiations on disarmament should take account of this basic interest of all States; therefore all States should be enabled to participate in the formulation of disarmament instruments.

(c) In carrying out meaningful disarmament measures, States which have more weapons will have to give up more. Thus a special responsibility devolves on the nuclear weapon States in facilitating disarmament negotiations. All nuclear weapon States therefore should participate in such negotiations.

(d) Nuclear weapons constitute the gravest threat to mankind. Highest priority should therefore be given to measures leading to nuclear disarmament.

(e) Development and use of other weapons of mass destruction should be prohibited as a matter of urgency.

(f) The important boost which disarmament will give to development efforts, and the importance to international peace and security of balanced world economic development dictates that efforts at meaningful disarmament negotiations be promoted so as to release vast human and material resources now tied to armaments for use to promote economic and social development particularly in the developing countries.

(g) Public awareness of the dangers of the armaments race both in its military and economic aspects should be emphasized. Thus adequate and regular information should be released so that public opinion in all countries may bring its influence to bear on disarmament efforts. In keeping with its responsibility for disarmament, the United Nations should launch a new programme for the promotion of disarmament awareness.

(h) The United Nations should be kept informed of all efforts on disarmament whether unilateral, bilateral or multilateral, so that it may co-ordinate these efforts.

Elements for the comprehensive programme

7. **Nuclear disarmament:** Utmost priority should be given to the cessation of the nuclear race through:

(a) urgent conclusion of a Comprehensive Nuclear Test Ban Treaty;
(b) a ban on the further development and testing of means of delivery of nuclear weapons;

(c) measures to achieve significant qualitative limitations on and substantial reductions in strategic nuclear weapons systems and the ultimate elimination of such weapons;

(d) establishment of nuclear-weapon-free zone in various regions and complete prohibition of the introduction of such weapons into areas where they now do not exist;

(e) cessation of the production of fissionable materials for military purposes and submission of all nuclear programmes of all countries to IAEA safeguards;

(f) promotion of peaceful uses of nuclear energy in all countries;

(g) encouragement of universal adherence to the NPT;

(h) complete prohibition of nuclear weapons.

Prohibition of weapons of mass destruction

8. (a) Prohibition of the development and manufacture of new types of weapons of mass destruction and new systems of such weapons, whether based on new scientific principles or on existing principles.

(b) Prohibition of the development, production and stockpiling of all chemical weapons.

(c) Prohibition of the use of all chemical, bacteriological and radiological weapons.

Collateral measures of disarmament

9. Bearing in mind the link between disarmament and development, effective measures must be taken to progressively free resources now being devoted to armaments for economic and social development particularly in the developing countries. To this end,

(a) Urgent measures for the reduction of the military budgets of nuclear-weapon States and other States with comparable military budgets and earmarking the savings for economic and social development particularly of the developing countries.

(b) Annual United Nations sponsored programme to promote public awareness of the dangers of the arms race, its effect on international peace and security, its economic and social consequences and its effect on the attainment of a new international economic order.

Conventional weapons and armed forces

10. (a) Prohibition of the development, production and deployment of new types of conventional weapons.
Gradual reduction of armed forces of States to levels necessary for the maintenance of internal order and defence of territorial integrity.

General and complete disarmament

11. The elaboration of a Treaty on general and complete disarmament should be continued pari passu other measures outlined above, with the participation of all States.

Machinery

12. (a) The General Assembly of the United Nations having adopted the comprehensive Programme of Disarmament should also decide on a precise time-table and schedule for the consideration and negotiation of specific instruments and other measures so that the entire process is completed by the end of the next decade.

(b) The General Assembly should make regular review of progress made on disarmament at its annual regular sessions and at periodic special sessions held not later than five yearly intervals.

(c) The Conference of the Committee for Disarmament should continue to be the main negotiating body under the auspices of the United Nations.

(d) To make the Conference a more realistic and effective forum it should be restructured to enable the participation of all nuclear-weapon States in it.

13. Restructuring the CCD should include:

(a) Abolition of the system of Co-Chairmen.

(b) Expansion by a modest figure consistent with efficiency and equitable representation.

(c) Greater link between CCD and the United Nations and revision of its rules to permit participation of non-members which show interest in the subject being negotiated.

(d) Encouragement of parallel disarmament negotiations on specific items in the comprehensive programme provided that the United Nations shall be given regular reports of such negotiations.
PAKISTAN

Working paper submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament

Declaration on Disarmament (A/AC.187/91)

PAKISTAN

Working paper submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament

Programme of Action on Disarmament (A/AC.187/92)

Report of the Ad Hoc Group of Scientific Experts to Consider
International Co-operative Measures to Detect and to
Identify Seismic Events

Letter dated 9 March 1978 from the Chairman of the Ad Hoc Group of
Scientific Experts to Consider International Co-operative
Measures to Detect and to Identify Seismic Events to the
Co-Chairmen of the Conference of the Committee on Disarmament
Transmitting the final report of the Ad Hoc Group

I have the honour to forward herewith the report on questions of considering
international co-operative measures to detect and identify seismic events prepared
by the ad hoc group of scientific experts under the auspices of the Conference of
the Committee on Disarmament, pursuant to the decision of the Conference of the
Committee on Disarmament adopted at its 520th meeting of 22 July, 1976.

The ad hoc group would like to note with appreciation the assistance which
the Secretariat of the United Nations provided to it.

The ad hoc group of scientific experts requested me, as its Chairman, to
transmit on its behalf the report, which was adopted unanimously.

Accept, Sir, the assurances of my highest consideration.

(Signed) Ulf ERICSSON
Chairman

and 22 May 1978.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SUMMARY</strong></td>
<td>34</td>
</tr>
<tr>
<td><strong>1. INTRODUCTION</strong></td>
<td>40</td>
</tr>
<tr>
<td>A. Terms of reference of the ad hoc group as established by the CCD</td>
<td>40</td>
</tr>
<tr>
<td>B. Organization and composition of the expert group</td>
<td>41</td>
</tr>
<tr>
<td>C. Programme and method of work</td>
<td>45</td>
</tr>
<tr>
<td><strong>2. A REVIEW OF EARLIER RELEVANT STUDIES</strong></td>
<td>47</td>
</tr>
<tr>
<td><strong>3. DATA AND PROCEDURES TO BE USED FOR DETECTION AND LOCATION OF SEISMIC EVENTS AND FOR OBTAINING IDENTIFICATION PARAMETERS</strong></td>
<td>51</td>
</tr>
<tr>
<td>A. Data and procedures for detection and location of seismic events by a network of arrays and single stations</td>
<td>52</td>
</tr>
<tr>
<td>B. Data and procedures for obtaining identification parameters of seismic events at individual stations</td>
<td>55</td>
</tr>
<tr>
<td>C. Data and procedures for obtaining identification parameters of seismic events from networks of stations</td>
<td>57</td>
</tr>
<tr>
<td><strong>4. SELECTION OF SEISMOGRAPH STATIONS FOR A GLOBAL NETWORK</strong></td>
<td>61</td>
</tr>
<tr>
<td>A. Technical description of existing stations of potential interest for the network</td>
<td>62</td>
</tr>
<tr>
<td>B. Data produced at these stations and present station capabilities</td>
<td>63</td>
</tr>
<tr>
<td>C. Additional data required from existing stations</td>
<td>63</td>
</tr>
<tr>
<td>D. Specification of a global network</td>
<td>64</td>
</tr>
<tr>
<td><strong>5. ESTIMATED CAPABILITY OF THE SPECIFIED GLOBAL SYSTEM</strong></td>
<td>72</td>
</tr>
<tr>
<td>A. Estimated global detection capability for seismic events</td>
<td>74</td>
</tr>
<tr>
<td>B. Estimated global location capability for seismic events</td>
<td>75</td>
</tr>
<tr>
<td>C. Estimated global capability to obtain identification parameters for seismic events</td>
<td>76</td>
</tr>
<tr>
<td><strong>6. DATA EXCHANGE BETWEEN SELECTED STATIONS AND INTERNATIONAL DATA CENTRES</strong></td>
<td>83</td>
</tr>
<tr>
<td>A. Description of existing data exchange facilities</td>
<td>84</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Data to be exchanged</td>
<td>86</td>
</tr>
<tr>
<td>C. Time-scale, data format and data channels to be used for the</td>
<td>87</td>
</tr>
<tr>
<td>global co-operative system</td>
<td></td>
</tr>
<tr>
<td>7. INTERNATIONAL CENTRES FOR COLLECTION, PROCESSING AND EXCHANGE OF</td>
<td>90</td>
</tr>
<tr>
<td>SEISMIC DATA</td>
<td></td>
</tr>
<tr>
<td>A. Description of some existing data centres</td>
<td>91</td>
</tr>
<tr>
<td>B. Tasks and work to be carried out at the international data centres</td>
<td>93</td>
</tr>
<tr>
<td>of a global network</td>
<td></td>
</tr>
<tr>
<td>C. Procedures to be used for data exchange and dissemination</td>
<td>94</td>
</tr>
<tr>
<td>8. EQUIPMENT AND ESTIMATED COSTS TO ESTABLISH AND OPERATE THE SPECIFIED</td>
<td>96</td>
</tr>
<tr>
<td>SYSTEM</td>
<td></td>
</tr>
<tr>
<td>A. Equipment and estimated costs to establish and operate</td>
<td>97</td>
</tr>
<tr>
<td>seismograph stations</td>
<td></td>
</tr>
<tr>
<td>B. Equipment and estimated costs for transmitting data between</td>
<td>98</td>
</tr>
<tr>
<td>stations and data centres</td>
<td></td>
</tr>
<tr>
<td>C. Equipment and estimated costs to establish and operate</td>
<td>99</td>
</tr>
<tr>
<td>international data centres</td>
<td></td>
</tr>
<tr>
<td>9. PROPOSAL FOR AN EXPERIMENTAL EXERCISE</td>
<td>105</td>
</tr>
<tr>
<td>A. Proven and unproven elements of the co-operative system</td>
<td>106</td>
</tr>
<tr>
<td>B. Outline of an experimental exercise</td>
<td>107</td>
</tr>
<tr>
<td>GLOSSARY</td>
<td>108</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS OF SEISMOGRAPH STATIONS</td>
<td>114</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>117</td>
</tr>
</tbody>
</table>

APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Problems with the estimation of yields of contained underground</td>
<td>126</td>
</tr>
<tr>
<td>nuclear explosions</td>
<td></td>
</tr>
<tr>
<td>II. Appendix to chapter 2: a review of earlier relevant studies</td>
<td>130</td>
</tr>
<tr>
<td>III. Appendix to chapter 5: estimated capability of the global network</td>
<td>140</td>
</tr>
<tr>
<td>IV. Appendix to chapter 7: description of some existing data centres</td>
<td>182</td>
</tr>
<tr>
<td>V. Paper submitted to the ad hoc group from the USSR expert on the</td>
<td>197</td>
</tr>
<tr>
<td>identification of seismic events</td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY

On 22 July 1976, the Conference of the Committee on Disarmament (CCD) established an ad hoc group of government-appointed experts to consider and report on international co-operative measures to detect and identify seismic events, so as to facilitate the monitoring of a comprehensive test ban.

The CCD decided that the group was to be guided by the following terms of reference:

"For the purpose of carrying out this investigation the Group should specify the characteristics of an international monitoring system inter alia including:

(1) A global network of seismological stations, selected from existing and planned installations;

(2) Data required from the stations to facilitate the analysis for detecting, locating and identifying seismic events;

(3) Transmission facilities for the timely exchange of data between seismological stations and data centres;

(4) Facilities, procedures and related financial implications with respect to contributing and receiving centres for detecting, locating and identifying seismic events throughout the world and facilitating the collation and dissemination of relevant documentation;

(5) The costs which would be incurred if an international monitoring system were established.

In addition to the items listed above, the Group would endeavour to estimate the detection and identification capability of such an international co-operative system. The estimates would be on the basis of available data, or, where desirable and feasible, also on the basis of data obtained from experimental exercises involving the whole or part of the specified global network. The Group should not, however, assess the adequacy of such a system for verifying a comprehensive test ban. Rather it should provide factual results of its analysis for the benefit of Governments to assist them in making such an assessment and in directing future research. The responsibility of the Group would be purely scientific."

The consensus report describes how seismological science can be applied in a co-operative international effort to facilitate the verification of a comprehensive test ban. The co-operative international effort would have three elements: a systematic improvement of the observations reported from a network of more than 50 seismological observatories around the globe, an international exchange of these data over the Global Telecommunications System of the World Meteorological Organization, and processing of the data at special international data centres for the use of participant States. The report also considers some steps, such as an experimental exercise, which could be taken initially to assist the establishment of such a co-operative data exchange system.
The report of the ad hoc group has nine chapters, written in a generally non-technical language in order to facilitate its reading by non-specialists in the field of seismology. Technical and detailed material is presented in separate appendices. A glossary and an extensive bibliography of the special topics under study have also been provided. The report was largely built on more than a hundred informal working papers contributed by the participants. These papers were deposited with and can be obtained from the CCD secretariat. Some of them have been issued also as formal CCD documents or been published elsewhere.

This summary has been made extensive enough to be a useful short version of the main body of the report and to give some indication of what further steps might have to be taken to achieve the co-operative measures envisaged. However, the reader should refer to the main body of the report if reference is to be made to a specific technical point. The report has deliberately been written as a consensus document. The wide area of consensus reached by the experts after careful considerations and discussions can be adequately seen only by reading the full report. Supporting details and additional viewpoints may be found in the informal working papers contributed by experts and groups of experts during the preparation of this report, in working papers presented to the CCD from time to time, and in the open scientific literature. The references to many of these are listed in the bibliography attached to this report.

This document reports on a study which the ad hoc group of experts has made on the basis of the latest results of seismological science, and which the group believes will provide most valuable and useful guidelines for facilitating co-operative measures to detect and identify seismic events.

Chapter 1 of this report is an introductory chapter, in which the terms of reference of the ad hoc group are reproduced, the organization and composition of the group is described and its programme and method of work are outlined.

Chapter 2 gives a brief review of earlier studies relevant to the detection and identification of seismic events. Substantial progress has been made in this field since the nuclear-test-ban issue was first raised in the middle of the 1950s. Numerous national research programmes as well as multinational undertakings have contributed in this respect, and the chapter gives a brief review of the most significant developments to date. Further details of a more technical nature including a discussion of current research efforts are presented in a separate appendix. The review is primarily intended to be a historical survey. No attempt has been made to assess the results and conclusions of the studies mentioned, and the ad hoc group does not necessarily consent to the viewpoints given in these earlier studies.

In chapter 3 procedures are discussed for extracting and reporting data from individual stations in a global co-operative seismic network. The main features of the recommended procedures are:

(i) Data are to be reported from each station in standard form in two levels:
   - Level 1: Routine reporting, with minimum delay, of basic parameters of detected seismic signals
   - Level 2: Data transmitted as response to requests for additional information, mainly waveforms for events of particular interest.
Compared to current seismological practice, increased emphasis is laid on parameters relevant to event identification.

Strict operation requirements are set forth as to scope, consistency, reliability and promptness in the reporting.

The procedures to be applied for detection, location, and evaluation of magnitude and depth of seismic events would follow practice now standard at existing international seismological centres. The ad hoc group considers it outside its mandate to recommend criteria to be used for the identification of seismic events.

Chapter 4 deals with the selection of seismograph stations for a global network. In summary the ad hoc group considers that a global network should comprise around 50 existing or planned seismic observatories, selected in accordance with seismological requirements. It is not known which States would actually make their stations available to a global co-operative system. Therefore, the ad hoc group has chosen to present four examples of possible global networks, each of which is based on different assumptions:

- Network I is based on stations for which information was provided to the ad hoc group (the group requested such information from a number of States)
- Network II includes at least one station from each CCD member State that operates seismograph facilities
- Network III is selected from among all known existing and planned stations according to purely seismological criteria
- Network III (SRO) is similar to Network III, but with each station hypothetically equipped with high-quality instrumentation.

Maps showing the location of the stations in the networks are given in figures 4.1 to 4.3.

Chapter 5 is on the estimated capability of the specified global system. The expected capabilities of Networks I, II, III and III (SRO) defined in chapter 4 have been estimated on a theoretical basis.

The networks have a significantly greater sensitivity in the northern than in the southern hemisphere with regard to detection and location of seismic events as well as obtaining identification parameters. The estimated capabilities are presented in the form of contoured world maps, in figures 5.1 to 5.5. These estimates depend on the confidence level at which a seismic event is considered to be satisfactorily detected and located. The results for the network with the highest capabilities (Network III (SRO)) are summarized by the following examples:

- Network detection capability for P-waves: A 90 per cent chance of detecting (at at least four stations) an event of $m_b 3.8$ to $4.2$ (or greater) in the northern hemisphere and of $m_b 4.0$ to $4.6$ (or greater) in the southern hemisphere.
- **Network location capability:** For a surface event of $m_b=5.0$, a 95 per cent chance of locating the event epicentre by at least four stations with an error not exceeding 10-20 km in most of the northern hemisphere, and not exceeding 20-50 km in the southern hemisphere.

- **Network detection capability for surface waves:** A 90 per cent chance of detecting (at at least four stations) surface waves from an event of $M_s \geq 3.0$ to $3.4$ (or greater) in the northern hemisphere and of $M_s \geq 3.4$ to $3.8$ (or greater) in the southern hemisphere.

The estimates for the four networks presented in this chapter are based on a number of explicitly stated, idealized conditions and assumptions: they can only be verified by performing an experiment with actual data over an extended period of time.

No attempt has been made in this study to incorporate probabilistic models for seismic identification based upon a number of signal characteristics. Also, no attempt has been made to assess the effectiveness of individual identification parameters.

The estimated capabilities are based on existing or planned seismographic installations, or as in the case of Network III (SRO), on the hypothetical modernization of the equipment at these installations. These estimated capabilities assume that the data from each station of each network considered are rigorously and diligently analysed according to procedures not all of which are found in common practice at seismographic installations today. It should be noted, however, that improved capabilities in some areas could be achieved (given adequate funds and data analysis) by a network extensively employing proven state-of-the-art seismic array and communications technology. The evaluations should be viewed as an illustration of the possibilities, based on the method of calculation used. Further improvements in seismic networks or methods of identification will improve the capabilities of the networks presented in this report.

Chapter 6 is on data exchange between selected stations and data centres. The ad hoc group has reviewed and assessed several possible media for seismic data exchange at Levels 1 and 2 (defined in chap. 3). The consensus of the group is:

- For Level 1 data (basic signal parameters) usage of the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO) is recommended because of its global availability, proven operation and low cost.

- For Level 2 data (requested waveforms) which are generally more voluminous and not so critically dependent on fast communication, several solutions might be employed. Digital transmission (e.g., via WMO/GTS) should be used when possible; otherwise, telecopying of seismograms is recommended in preference to using mail services.

Consideration has also been given to the time delays that would be involved in the data exchange. The ad hoc group considers that realistic goals in this respect are:

- Maximum 3-5 days delay in the reporting and processing of Level 1 data
- Maximum 4-6 weeks delay (after request) in obtaining Level 2 data. As operational experience is gained, this delay should be considerably reduced.

The use of the GTS for transmission of seismic data in general, has already been authorized by the WHO. According to information available to the ad hoc group, the excess capacity of the GTS is sufficient to handle the expected load from the proposed data exchange.

In order to use the WHO/GTS for data exchange within the global network it will be necessary to obtain an official agreement through the appropriate international organizations.

In chapter 7 international centres for collection, processing and exchange of seismic data are considered. In summary, the ad hoc group considers that special international data centres should be established for the global network. In order to achieve a reliability acceptable to all, it is proposed that more than one standardized international centre be established, thereby following practice established inter alia by the World Meteorological Organization (WMO), having communication centres in Moscow, Washington, D.C., and Melbourne. In connexion with the use of WMO/GTS for data exchange it is desirable, for technical and other reasons, to locate International Data Centres in the places where main WMO communications centres are situated, such as in Moscow (USSR) and Washington, D.C. (USA). The Group recognizes that it would be desirable and technically feasible to establish International Data Centres in other places as well, e.g. in the southern hemisphere.

The main tasks of the international centres will be:

(i) to receive data of Levels 1 and 2 from the world network of seismic stations via the authorized Government facility of each State

(ii) to apply agreed analysis procedures to available data for the estimation of the origin time, location, magnitude and depth of seismic events

(iii) to associate reported identification parameters with these events

(iv) to distribute, in accordance with defined procedures and without interpretation of identification parameters, compilations of the complete results of these analyses

(v) to act as an archive for reported data and results of analysis on those data.

The international centres should be equipped with equivalent hardware and software. Each centre would perform equivalent processing of all Level 1 data. If requested, the centres would ask for and forward Level 2 data.

Chapter 8 is about equipment and estimated costs to establish and operate the specified system. The three major components of the proposed co-operative system are (i) the seismograph stations, (ii) the data communications facilities and (iii) the international data centres:

(i) For the equipment at seismograph stations, two degrees of sophistication have been considered:
- The minimum equipment required for participation comprises standard instrumentation that is already available at most stations under consideration.

- The desirable equipment at each station would be modern, high-quality instrumentation which would ensure data acquisition in numerical form.

(ii) The requirements for data communications consist of a telex terminal and communication lines to interface the World Meteorological Organization (WMO) network and of equipment for exchanging seismograms.

(iii) The requirements at an international data centre consist of a modern, medium-size computer facility with associated equipment, including two small special purpose computers for data communications. Special software for the communications and data analysis tasks will be needed.

The expected cost and manpower to establish and operate the system cannot be given in detail, due in part to the great variations of cost levels between countries. Order of magnitude estimates are included for purposes of illustration, and are summarized in table 8.2.

Chapter 9 contains a proposal for an experimental exercise.

The international co-operative measures described in this document contain a number of elements that are new and unproven relative to past and current seismological practice. The ad hoc group therefore sees a need for an experimental exercise in order to:

- test the over-all functioning of the proposed system

- determine experimentally the operating efficiency and any possible deficiencies of the specified system, including its capabilities in the southern hemisphere

- test the telecommunications and data exchange procedures in a practical situation

- obtain practical experience and thereby shorten the lead time necessary for the implementation of a procedure for international exchange of seismic data should this later be decided.

The experimental exercise would address the main elements of the international co-operative measures described in this document. A time period of at least six months would be required for the planning and co-ordination of such an exercise. An additional period of approximately one year would be required for the execution and evaluation of the experimental exercise.
CHAPTER 1
INTRODUCTION

Summary

The terms of reference of the Ad Hoc Group are reproduced, the organization and composition of the Group is described and its programme and method of work are outlined.

1a. Terms of reference of the Ad Hoc Group, as established by the CCD

On 22 July 1976, the Conference of the Committee on Disarmament decided as follows (see also CCD document CCD/520 of 3 September 1976):

"The Conference of the Committee on Disarmament, having considered the proposal made by the delegation of Sweden at its 704th Plenary meeting on 22 April 1976, agrees to establish, under its auspices, an Ad Hoc Group of Scientific Experts to consider international co-operative measures to detect and identify seismic events.

Membership in the Ad Hoc Group will be open to scientific experts nominated by any CCD member State. In order to enable the group to draw on expertise of other States, membership in the Ad Hoc Group will also be open to scientific experts nominated by States Members of the United Nations that are not represented in the CCD, upon invitation of the CCD. By nominating experts to participate in the Group, States do not commit themselves to the adequacy of the international co-operative measures studied.

The Ad Hoc Group will hold its first meeting during the week beginning 2 August. The CCD requests that the Group submit a progress report to the CCD before the end of the 1976 session.

The CCD decides that the Group shall elect its own Chairman. It further decides that the Group should seek to achieve consensus in its reports and that, whenever consensus cannot be achieved, each expert will be entitled to incorporate his own view.

The Group should carry out its work on an informal basis, with unofficial working papers and proceedings, as deemed necessary. The report of the Group to the CCD will be prepared on a formal basis.

The CCD requests that the Secretariat undertake to provide the Group with the necessary assistance and services.

The CCD decides that the Group will be guided by the following terms of reference:

For the purpose of carrying out this investigation the Group should specify the characteristics of an international monitoring system inter alia including:
(1) A global network of seismological stations, selected from existing and planned installations;

(2) Data required from the stations to facilitate the analysis for detecting, locating and identifying seismic events;

(3) Transmission facilities for the timely exchange of data between seismological stations and data centres;

(4) Facilities, procedures and related financial implications with respect to contributing and receiving centres for detecting, locating and identifying seismic events throughout the world and facilitating the collation and dissemination of relevant documentation;

(5) The costs which would be incurred if an international monitoring system were established.

In addition to the items listed above, the Group would endeavour to estimate the detection and identification capability of such an international co-operative system. The estimates would be on the basis of available data or, where desirable and feasible, also on the basis of data obtained from experimental exercises involving the whole or part of the specified global network. The Group should not, however, assess the adequacy of such a system for verifying a comprehensive test ban. Rather it should provide factual results of its analysis for the benefit of Governments to assist them in making such an assessment and in directing future research. The responsibility of the Group would be purely scientific.

lb. Organization and composition of the Expert Group

As indicated in the terms of reference above, membership in the Ad Hoc Group was open to scientific experts nominated by CCD member States and by States Members of the United Nations not represented in the CCD, upon invitation of the CCD. Altogether, scientific experts and representatives from 21 member States of the CCD and from 6 other States participated in the work of the Ad Hoc Group. The names of the participants are listed at the end of this paragraph. Dr. Ulf Ericsson of Sweden served as chairman and Dr. Frode Ringdal of Norway as scientific secretary. The meetings of the Ad Hoc Group were assisted by the secretariat of the CCD and the services of the United Nations in Geneva. Mr. P. Csillag, Chief of the Information and Research Section of the United Nations Centre for Disarmament, served as secretary of the Ad Hoc Group. A number of experts acted, during and between sessions, as convenors of temporary working groups and, together with other experts, as contributors of the substantial parts of the report.

The participating scientific experts and representatives were:

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-43-
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Mr. O. Ionescu
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SWEDEN

Dr. U. Ericsson (Chairman)
Scientific Adviser, Ministry of Foreign Affairs

Dr. O. Dahlman
Head of Section, National Defense Research Institute

Dr. H. Israelson
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Mrs. B. M. Tygard
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Dr. F. Ringdal (Scientific Secretary)
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1c. Programme and method of work

The Ad Hoc Group met in five sessions at Geneva, on the following dates:

1st session 2-6 August 1976
2nd session 21-25 February 1977
3rd session 25-28 April 1977
4th session 25 July-5 August 1977
5th session 27 February-10 March 1978

The Group's report was to be presented to the CCD early during its spring session, 1978. The method of work was informal, with appointed convenors and working parties preparing drafts of chapters between sessions, review of these drafts at plenary sessions and finally comprehensive redrafting and editing by

-45-
the scientific secretary, aimed at obtaining a consensus report, in generally accessible language and with technical material in separate appendices. The entire draft report was reviewed and finalized in its present form during the fifth and last session of the Group.

During the work of the Ad Hoc Group, more than 100 informal scientific working papers were contributed. These were all deposited with and can be obtained from the CCD secretariat. Some of these working papers have also been made into formal CCD documents or have been made public elsewhere. Conference Room Papers produced by the Ad Hoc Group during its sessions were also deposited with the CCD secretariat. Progress reports to the CCD, submitted after each of the first four sessions, were reproduced as CCD documents CCD/513, CCD/528, CCD/534 and CCD/542.
CHAPTER 2

A REVIEW OF EARLIER RELEVANT STUDIES

Summary

Substantial progress has been made in the field of detecting and identifying seismic events since the nuclear test-ban issue was first raised in the middle of the 1950s. Numerous national research programmes as well as multinational undertakings have contributed in this respect, and the present chapter gives a brief review of the most significant developments to date. Further details of a more technical nature including a discussion of current research efforts are presented in Appendix II. The review is primarily intended to be a historical survey. No attempt has been made to assess the results and conclusions of the studies mentioned, and the Ad Hoc group does not necessarily consent to the viewpoints given in these earlier studies.

Background

At the invitation of the United Nations Disarmament Commission, an International Group of Experts met in Geneva in 1958 to study the technical aspects of nuclear test ban monitoring. Particular attention was given to problems of detecting and identifying underground nuclear explosions, and the group concluded that by seismic means this would indeed be feasible. However, this conclusion was based upon the limited explosion data available at the time (only one underground nuclear test, the 1.7 kt. Rainier explosion of 19 September 1957). Several test explosions conducted later in that same year showed that the views of some of the experts had been somewhat optimistic. Nevertheless, judging from subsequent developments, the expert meeting in Geneva in 1958 must be credited with exceptional foresightedness in the problems at hand. For example, the group envisaged the need for a homogeneous network of globally distributed seismograph stations of high operational sensitivity for body waves as well as surface waves and an efficient system of international data exchange. It further introduced the concept of arrays of closely spaced sensors to improve the detectability of seismic signals. Evasion possibilities such as hiding explosions in the "wake" of nearby earthquakes were also foreseen. In retrospect, this study influenced several countries, notably USSR, UK and USA, to promote seismological research on an unprecedented scale. The Berkner Panel for Seismological Improvements was particularly influential in stimulating research and development in the USA.

Progress which followed in seismic instrumentation, data analysis and basic research was encouraging enough to allow for considerable optimism following the Partial Test Ban Treaty of 1963 (PTBT) regarding the possibility of realizing a verifiable Comprehensive Test Ban (CTB). Possibilities were discussed for expanding the scope of the PTBT to include underground testing of nuclear weapons, carrying out the control by national technical means supplemented with international exchange of seismological data. Such discussions took place in the Eighteen Nation Disarmament Committee by the 8 member group of non-aligned member countries, first on 14 September 1964, and later between 27 July and 16 September 1965.
Consequently, the United Nations General Assembly expressed its conviction through resolution 2032 (XX) of 3 December 1965, that improvements in seismic discrimination techniques along with the possibility of international data exchange would facilitate an early agreement on a CTB. Presumably encouraged by this expression of political will, several countries, particularly USSR, UK and USA, but also, among others, Canada, Federal Republic of Germany, France, German Democratic Republic, India, Norway and Sweden, have since been devoting considerable attention to research and development projects relevant to a CTB. These efforts led to the establishment of high-quality seismic stations and networks of stations designed to provide the basis for improving methods of extracting signals from interfering noise and for developing techniques to identify seismic sources.

**Post PTBT improvements in seismic instrumentation**

The 1963 PTBT was followed by rapid and significant improvements in seismic data acquisition systems around the world. Notable among these were the two major international networks of standard seismographs. The World Wide Standardized Seismograph Network (WWSSN) was installed by the United States and maintained by the voluntary co-operation of several countries around the world. A similar, national, network was established in Canada. The second international network of standard stations was set up in the socialist countries of Europe through the initiative of USSR. By choosing sites of low seismic noise, shaping instrumentation characteristics to enhance detectability of seismic waves and ensuring calibration integrity, the threshold for detecting world-wide seismic events was considerably improved through the establishment of the WWSSN. The seismic network of the European socialist countries pioneered the use of wideband seismographs which, at some expense in sensitivity, were capable of reproducing ground motion with minimal distortion.

Based on the scientific success of the WWSS network, the United States developed a new generation of sophisticated seismological instrumentation (Seismic Research Observatories - SRO). About 15 SRO stations (CCD 491-1976) are now being established at selected WWSSN locations. With greater care in the choice of sites, provision for digital recording, automatic event detection and rapid data communication to a central analysis facility, this new system in conjunction with existing and projected arrays will provide a data base of exceptional value.

Seismic arrays of the type advocated by the 1958 Geneva expert conference were installed only at a few locations on an experimental basis and were later superseded by larger and more sophisticated array stations. Noteworthy among these were the medium-size arrays pioneered by the United Kingdom in co-operation with Australia, Brazil, Canada and India. In turn, the United States developed a generation of still larger arrays, one of which was installed in Norway. A number of other countries have also built seismic array stations in recent years. With their ability to carry out independent, rapid searches for low-level seismic activity, arrays have become an important tool in modern seismology and have in particular improved the global detection capability of seismic events.
Multinational co-operative research efforts

In 1965, Sweden initiated discussions among a number of States on the subject of seismic detection of underground nuclear explosions. The first meeting was attended by representatives from Australia, Canada, India, Poland, Romania, Sweden and the United Arab Republic. The objective was to promote multinational data exchange and thereby enable each individual country to evaluate the seismic detection and identification potential of the combined data. After installing the Hagfors array, Sweden joined with Canada and Japan in co-operative studies on the identification problem. Methods for identification and depth estimation were developed and applied to groups of seismic events from Eurasia, using common data bases. These efforts resulted in the development of multistation identification techniques, which demonstrated that for Eurasia earthquake-explosion separation is significantly improved by the use of data from several stations.

It should be noted that a probability approach to the identification of seismic events based on a number of signal characteristics was developed earlier by scientists of the Soviet Union.

SIPRI-SPONSORED international study - 1968

In 1968, experts from Canada, Czechoslovakia, France, India, Japan, Romania, Sweden, USSR, UK and USA met informally at the invitation of the Stockholm International Peace Research Institute (SIPRI), Sweden. Their purpose was to review the state of art of seismic identification. A number of criteria devised to provide identification information of seismic sources were reviewed, and in particular the effectiveness of identification by magnitudes ($M_s$: $M_b$) was recognized. Moreover, an effort was made to assess the problem of relating the seismically measured magnitude to explosion yield for different source conditions. The group also discussed the significance and implications of the disparity between different magnitude scales based on instruments having different characteristics. As an example, it was noted that magnitude estimates of low-yield underground explosions determined by the United States network were observed to be 0.3-0.5 $M_b$ units lower than those determined by the network of the Soviet Union. Some of the conclusions of the SIPRI conference are summarized in appendix II.

United Nations assessment of world-wide data availability - 1969

The continued efforts of Canada in the CCD led to the United Nations General Assembly resolution 2604 A (XXIV) of 16 December 1969, which requested each member country to furnish details of the seismograph stations within its territory, the data from which would be made available for use in an international scheme for identifying underground nuclear explosions. A total of 45 nations furnished details of 300 seismograph stations, about 10 of which were of the array type. The details of this data resource and projections of world-wide detection, location and identification potential based on the declared stations were analysed in an exhaustive study described in the Canadian working paper CCD/305, 1970. Its main conclusions are summarized in appendix II.

Assessments of the capabilities of seismic networks

From 1968 and up to present several studies have been made to evaluate the detection and identification capability of large seismograph networks and to assess their source location accuracy. However, there has been only one
international co-operative experiment to evaluate the potential of data from operational seismograph networks. Co-ordinated by the Lincoln Laboratories, USA, it had participation of seismologists from Canada, Japan, Norway, Sweden, UK and USA. The data covered a one-month period from 20 February to 19 March 1972, and were derived from a global network of 150 stations which included the large arrays in the USA and Norway and several medium-size arrays along with standard stations of the WWSSN. Detection and location estimates of this experiment, which is known as the International Seismic Month (ISM), were compared with those derived from a smaller subset of 32 stations selected to provide good geographical distribution and high detection efficiency. The conclusion reached from this comparison was that carefully analysed data from a few but well-selected stations are considerably more effective in a seismic identification context than those reported less meticulously from a much larger network. The ISM experiment also provided an indication of the large practical problems of associating the data of smaller events in order to determine location estimates. The main results of the study are summarized in appendix II.

Rapid exchange and collation of seismic data

The latest developments in communications technology have been adapted to transfer seismic data from a number of countries to data centres such as the National Earthquake Information Service and the Seismic Data Analysis Center (both in USA) and the Blacknest Laboratory of the UK (see chapter 7). The ARPA communication network (see chapter 6), established by the USA, is designed for rapid and reliable data exchange between large computer centres, and is used as one of the communication channels for seismic data between various centres and facilities. Facilities for rapid transfer of seismic data to national headquarters also exist in a number of other States, e.g. China, Finland, France, Japan and the Soviet Union.

Prospects

The numerical details of some of these research activities may be found in appendix II. While the Ad Hoc group does not accept that the results of individual programmes are necessarily representative, there is evidence of more agreement on the real capabilities and limitations of verification by seismic means than there was 20 years ago. There is evidence too of prospects for further reduction of the uncertainties and of narrowing the remaining areas of disagreement. The following chapters of the report indicate the way these prospects might be realized.
CHAPTER 3
DATA AND PROCEDURES TO BE USED FOR DETECTION AND LOCATION OF
SEISMIC EVENTS AND FOR OBTAINING IDENTIFICATION PARAMETERS

Summary

This chapter discusses procedures for extracting and reporting data from
individual stations in a global co-operative seismic network. The main features
of the recommended procedures are:

(i) Data are to be reported from each station in standard form in two levels:

- Level 1: Routine reporting, with minimum delay, of basic parameters
  of detected seismic signals

- Level 2: Data transmitted as response to requests for additional
  information, mainly waveforms for events of particular
  interest.

(ii) Compared to current seismological practice, increased emphasis is laid
    on parameters relevant to event identification.

(iii) Strict operational requirements are set forth as to scope, consistency,
     reliability and promptness in the reporting.

Introduction

The preceding chapter highlighted some of the most important achievements in
seismology over the past two decades. Improvements in signal detection
capabilities, event location accuracies and identification methods have been
significant, as have advances in the application of computer and communications
technology. A number of national and international seismic networks and data
centres have been established, and basic parameters of seismic events are today
reported routinely on this basis. In general, seismic network operations are
primarily aimed at detecting and locating events: parameters relevant to the event
identification problem are much less frequently reported. For a co-operative
international network as discussed by the Ad Hoc group, it therefore follows that
data and procedures for event detection and location can be built upon existing
and thoroughly tested operational routines. To establish procedures for obtaining
identification parameters on a similar basis will represent a major step forward
relative to current seismological practice, as will the rapid and global
dissemination of these data.
The station reporting procedures of a co-operative seismic system, as discussed in this document, must by necessity be more strict and more precisely defined than those used by many stations currently reporting to national or international seismological data centres. For example, seismogram analysts at some stations apply a variable threshold for detection or reporting depending on the level of seismicity or pressure of other duties on a particular day. These factors also affect the timeliness of many station reports. Moreover, in most cases secondary phases are not consistently reported. Without going into further detail here, it is obvious that clear reporting criteria will need to be established and strictly followed to create confidence in any proposed seismic data exchange system based on international co-operation.

3a. Data and procedures for detection and location of seismic events by a network of arrays and single stations

Part of the energy released by an earthquake or an explosion is converted into elastic waves, which propagate through the earth and can be registered instrumentally at considerable distances. These waves are classified into.

(i) **Body waves**, which propagate through the interior of the earth:

- P-waves, of the longitudinal type
- S-waves, of the shear type

(ii) **Surface waves**, which propagate along the earth's surface layers:

- Rayleigh (LR) waves, characterized by elliptic polarization in the vertical plane
- Love (LQ) waves, which are polarized in the horizontal plane

The P-wave (or primary wave) is the most important of these for event detection and location. All four wave types, notably the P and Rayleigh waves, are useful in an identification context. The size of a seismic event is usually specified by its body-wave magnitude ($m_b$) or surface wave magnitude ($M_s$): which are derived from the amplitudes of the P and Rayleigh waves, respectively.

Seismic body-waves show different characteristics depending on the distance from the source:

- In the first or near-regional zone, i.e., at distances less than 10 degrees (1 degree is about 111 km), signals generally show high amplitudes but are quite complex due to a transmission path through the strongly inhomogeneous upper layers of the earth.
- In the second or regional zone, from 10 to 25 degrees, signals are variable and usually relatively small in amplitude.
- In the third or teleseismic zone, from 25 to 100 degrees, the P-wave has traversed the deeper, more homogeneous layers of the earth, and thus it is much more predictable in amplitude.
The teleseismic signals are of most importance in the present context, both as regards detection, location and identification of seismic events. However, it should be recognized that, in certain cases, first and second zone observations can provide a valuable supplement in the analysis of events that are not satisfactorily located and classified using teleseismic data.

Instrumentation

Body waves from weak events are most effectively registered using short period (SP) seismographs, which are particularly sensitive to signals with a period of around 1 second. Surface waves are registered by long period (LP) instruments, having their optimum sensitivity at signal periods around 20 seconds. Broad-band seismographs, capable of registering signals in both the SP and LP bands, have recently come into use in an increasing number of countries.

The signal recording equipment forms an integrated part of any seismograph system. Common recording devices are paper or film, and the ground motion is magnified up to several hundred thousand times. However, the trend in recent years has been towards more increased reliance upon digital recording on magnetic tape, with ensuing benefits in terms of increased resolution and dynamic range and at the same time making possible extensive computer analysis of the signals.

In the global network envisaged by the Ad Hoc group, emphasis will be laid upon existing and planned digital seismic observatories, both of the array type and single seismograph installations. Due to a general lack of such facilities in many parts of the world, it will, in the initial period, be necessary to supplement these observatories with a number of existing stations without digital recording. From the experience gained in previous studies cited in chapter 2, the Ad Hoc group favours a limited network of about 50 high quality stations rather than a larger network with a lesser degree of homogeneity. Details on the station selection will be further addressed in chapter 4.

Detection

Although seismic waves generated by any earthquake or explosion propagate over great distances, they may or may not be detected at a given seismograph installation. The most important factor here is the presence of seismic noise, i.e., slight vibrations of the earth's surface that tend to obscure waves from small seismic events. Much effort has been expended in recent years on designing and installing instrumentation so as to minimize the influence of seismic noise sources.

Of particular importance in achieving improved detection is the development of seismic arrays, which utilize the antenna principle to suppress seismic noise waves and at the same time provide a directional capability for detecting signal waves. A modern array installation generally has a dedicated computer which scans the data to detect signals by automatic processing methods, and at the same time computes rough locations, magnitudes and other signal parameters. In addition, it has automatic features for surveillance of system status and maintenance of calibration integrity. The standard procedure for event detection at most array stations is beam-forming by summation of time-aligned signals and comparison between short-term (2 to 3 seconds) and long-term averages of these beams. A detection is declared each time the short-term average exceeds the long-term average by a predetermined amount.
At conventional seismograph stations, on the other hand, detection of seismic signals is usually performed by an analyst examining the seismograms. A seismic wave phase is then detected as a sudden change in the character of the recorded waveform. Although quite subjective, this procedure generally yields good results. In fact, even in those cases where sophisticated automatic detectors are employed, analyst interaction and screening of the results is highly desirable for reducing the false detection rate.

In a global co-operative system as considered here, detailed technical procedures for reporting these detections will have to be defined and strictly adhered to by the participating stations. It will be the responsibility of each individual station to provide relevant detection data in a form consistent with network requirements. These data will be similar to those routinely reported to present international seismological centres, and detailed specifications will be given in section 3b.

Location

To obtain a reliable estimate of where a seismic event occurred, it is essential to have P-wave detection data available from a widely distributed network of seismic stations. In principle, readings from only four suitably located stations are required to determine the event hypocentre; however, the location accuracy increases with the number of reliable observations available. The task of locating seismic events is most conveniently carried out at special data centres, using standard computer programmes. The procedure to be employed for the global co-operative network would follow accepted practice in existing international seismological centres:

(i) Associate detections - Individual signal detections at different stations must be grouped and assigned to particular wave phases and events. Unless the event is known from other sources, the successful association of detections actually defines a detected event. Approximate locations and origin times from arrays are of great value in this fundamental process.

(ii) Compute locations from P-wave data - The procedure consists of comparing the observed arrival time of P-waves at each station with arrival times calculated from assumed event origin times and positions. Eventually, the location that best fits the observed data is selected as the hypocentre solution. In this process it is necessary to know the average velocity with which seismic waves propagate through the earth, and extensive travel-time tables have been developed for this purpose.

(iii) Refine location estimates - By using supplementary information of wave phases other than P, more reliable locations may be achieved. In particular, the so-called depth phases pP and sP (denoting waves that have been reflected from the earth's surface above the hypocentre) are valuable for improving depth determination. If available, observations from close-in stations may be used for improved control on location, depth and origin time.

The Ad Hoc group considers that the location procedures should also include provisions for taking advantage of recent developments such as:
(i) **Regional corrections** to the standard travel-time tables.

(ii) **Joint hypocentre estimation.** The essence of this method is to locate groups of events in the same region simultaneously, thereby improving the location estimate of each event relative to the others.

(iii) **Multiarray location techniques,** making use of the directional capabilities of arrays in addition to the travel-time data.

References describing these and other techniques of potential interest may be found in the bibliography.

As a general rule, the difficulties in locating seismic events increase with decreasing event magnitude. This is because the ambient earth noise tends to obscure weak waves at any given site. Hence, any network of stations has a magnitude threshold below which it cannot detect adequately, and both the detection capability and location accuracy decreases as this threshold is approached.

3b. Data and procedures for obtaining identification parameters of seismic events at individual stations

The fundamental differences in the wave generation mechanisms of earthquakes and explosions are expected to produce corresponding differences in the characteristics of signals registered at seismic stations. In practice, these expected differences can be obscured or completely masked by wave scattering, absorption, signal interference or simply the presence of seismic noise. Therefore, no single identification parameter can be assured to work in all cases, and a number of such parameters are generally required.

The analysis of the effectiveness of identification parameters and their actual use involves a wide range of geophysical, probabilistic and other considerations. The setting of criteria from which to judge identification data is, however, the responsibility of each individual State, and is therefore a matter outside the terms of reference of the ad hoc group. The presentation in this report has been limited to a brief description of the parameters most widely applicable in this context:

(i) **Depth of focus.** Underground explosions are not technically feasible below a depth of a few kilometres, while earthquakes may occur at much greater depths.

(ii) **$M_S: M_B$** (surface wave versus body-wave magnitude). Earthquakes tend to create relatively larger surface waves than underground explosions of comparable body-wave magnitude.

(iii) **Complexity of the P waveform.** Signals generated by earthquakes usually (but not always) appear much more complex than those originating from explosions.

(iv) **Signal spectrum.** For underground explosions, the frequency of recorded body waves and certain surface waves are in most cases higher than for earthquakes.
(v) First motion of the P-wave. For explosions the initial pulse is compressional at all azimuths and distances, while in the case of earthquakes in some directions some stations may record the first pulse as a rarefaction.

(vi) Dynamic characteristics of teleseismic P-waves. Methods have been suggested, as described in appendix V, to identify specific differences in the dynamic characteristics of P-waves from explosions and earthquakes, using a set of relatively simple parameters.

Most identification criteria require that the geographical location of the event be known to enable appropriate corrections to be made for the effects of propagation through the earth. Thus the co-operative system discussed in this document must attempt to locate the source of every detection by the seismic stations of the system, where "detection" implies the arrival of a discernible seismic phase at a given station.

The ad hoc group recommends that the data reported from individual stations should be divided into two stages or levels.

- **Level 1 data** should be reported routinely for all detections at each station and transmitted as soon as possible to the international data centres of the global network. These data would comprise basic parameters for detection and location as well as identification parameters. Level 1 data should as far as possible result from measurements that can be made both from seismograms and from digital and analog tape recordings.

- **Level 2 data** would generally consist of complete waveforms for events of special interest. Requests for Level 2 data would be initiated by individual States, and co-ordinated through approved international data collection centres for the global network. Level 2 data will especially be of interest for those events that cannot be confidently identified from a study of Level 1 data.

**Specification of Level 1 data**

Because of the numerous identification parameters available, a very extensive set of measurements is desirable at Level 1 for each individual detection. Against this must be weighted the desire to keep the data exchange manageable and within practical limits. Table 3.1 specifies the basic short period data proposed by the ad hoc group for reporting at Level 1, while table 3.2 lists the corresponding long period data. In these tables a distinction is made between (a) standard parameters, that should be reported uniformly by each station, and (b) additional standard parameters that would be reported only by seismic array stations. The standard parameters under (a) are quite extensive, and some of them (items 8 and 9 of table 3.1) can be measured only by stations of special capabilities. However, most of the proposed standard parameters consist of relatively simple measurements of arrival times, amplitudes and periods of ground motion that can be made at all stations.

It is strongly recommended that individual stations also report qualitative remarks that might help in the interpretation at the data centres. Comments like "regional" or "local earthquake", "local quarry explosion" or "mixed with earlier event" would be useful. Finally, each station should transmit calibration
and background noise data regularly and whenever these parameters change significantly.

The standard parameters listed in tables 3.1 and 3.2 form a comprehensive set of measurements, and will imply a considerable workload on each participating station. The ad hoc group recognizes that the capabilities of existing stations to provide these data differ greatly, and depend on instrument type, facilities for data reduction and available manpower. The ad hoc group does, however, see the provision of the standard parameters on a regular basis as one of the most desirable of the undertakings recommended in this document.

It may seem excessive to measure and report Level 1 data for each detection at every station. Since depth determination and location constitute in many cases an effective discriminant, only detection arrival time and phase identification may be required to eliminate many events from further consideration. However, experience has shown that it is unwise to attempt to identify an event on the basis of data from a single station or even a limited national network. For example, the possibility that two seismic events may occur within a short period of time complicates the phase identification at a single station. Therefore, Level 1 data should be reported for all detections, and each report should contain a complete set of parameters describing a given signal in accordance with an elaborated standard processing scheme.

Specification of Level 2 data

Level 2 data would consist mostly of analog and digital waveforms. The procedures to encode and transmit these data must be kept as standardized and uniform as possible. Certain additional measurements or analyses may be required at special stations, such as arrays, in the Level 2 reporting cycle. Examples of Level 2 data are given below.

(i) **Verification or review** of Level 1 data or of a detection or non-detection at a specific time.

(ii) **Waveform data** for specific time intervals - for example this might consist of 60 seconds of vertical component short period data and 20 minutes of three-component long period or broad-band data, both preferably in digital form. If data digitizing capability is lacking at a station, analog waveforms must be used instead. Digitization should begin at least 10 seconds before the arrival or expected arrival for short period data; at least 1 minute for long period data.

(iii) At arrays, further processing may be asked for, for example restreering of the array to a specified location or the application of various techniques for improved detection of weak signals. The results of these reanalyses would be transmitted to the international data centres as waveforms.

3c. **Data and procedures for obtaining identification parameters of seismic events from networks of stations**

The data required for obtaining identification parameters from a network of stations are essentially the same as those obtained from a single station.
However, since the radiation of energy from a seismic source is not, in general, symmetric, data from a network of stations can allow the seismologist to view a seismic event from several perspectives and thereby identify the source type with more confidence. It is essential that the data reported from a network of stations have the following qualities:

(i) be measured accurately and in a clearly defined manner
(ii) be reported to the international data centres in a standard format according to a timely and well-established schedule, and
(iii) be capable of rapid confirmation when requested.

Of these requirements the first may be the most difficult to achieve. Guidelines in the form of a handbook should be prepared for the station analysts in order to specify measurement techniques and to yield consistent data which are reducible to a common base. As set down in the previous section, the base of Level 1 identification parameters is to be made up of, chiefly, measurements of the arrival time, amplitude, and period of ground motion. Although amplitude and period are rather elementary parameters when compared with the potential capability of a modern, digital seismic observatory, they represent the highest level of measurement sophistication from which a homogeneous data base can be obtained from a large number of widespread stations. Every station of the network should be able to report these data easily and accurately. If good locations are to be achieved, the time base must also be accurately maintained relative to universal time.
**Short period Parameters**  
(Body waves-Vertical Component)

<table>
<thead>
<tr>
<th>a). Standard Parameters - All stations</th>
<th>Unit of Measurement</th>
<th>Precision of Measurement</th>
<th>Volume of Data (Computer Words)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Arrival time</td>
<td>hour,min,s</td>
<td>0.1 s</td>
<td>3</td>
</tr>
<tr>
<td>2. First motion sign and clarity</td>
<td>nm</td>
<td>0.1 nm</td>
<td>4</td>
</tr>
<tr>
<td>(if possible)</td>
<td>hour,min,s</td>
<td>0.1 s</td>
<td>12</td>
</tr>
<tr>
<td>3. *Amplitudes $A_j$ ($i=1,...,4$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. *Arrival times corresponding to each $A_i$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. *Periods corresponding to each $A_i$</td>
<td>s</td>
<td>0.1 s</td>
<td>4</td>
</tr>
<tr>
<td>6. Signal-to-noise ratio</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>7. Phase description,</td>
<td>nm</td>
<td>0.1 nm</td>
<td>1</td>
</tr>
<tr>
<td>Amplitude</td>
<td>s</td>
<td>0.1 s</td>
<td>1</td>
</tr>
<tr>
<td>Period</td>
<td>hour,min,s</td>
<td>0.1 s</td>
<td>3</td>
</tr>
<tr>
<td>Arrival time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of secondary phases, e.g.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S, PcP, PP,...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(reported when possible)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Complexity (digital stations only)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Spectral moment, ratio or vector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(digital stations only)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b). Additional Standard Parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Arrays Only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Apparent velocity</td>
<td>km/s</td>
<td>0.01 km/s</td>
<td>1</td>
</tr>
<tr>
<td>11. Epicenter azimuth and distance</td>
<td>degrees</td>
<td>0.01 degrees</td>
<td>2</td>
</tr>
<tr>
<td>12. Epicenter latitude and longitude</td>
<td>degrees</td>
<td>0.01 degrees</td>
<td>2</td>
</tr>
<tr>
<td>13. Estimated time at focus</td>
<td>hour,min,s</td>
<td>1 s</td>
<td>3</td>
</tr>
<tr>
<td>14. Magnitude $m_b$</td>
<td></td>
<td>0.1 unit</td>
<td>1</td>
</tr>
</tbody>
</table>

* The $A_j$, $i=1,2,...,4$ correspond to maximum amplitudes in the intervals 0-6 seconds, 6-12 seconds, 12-18 seconds and 18-300 seconds after P-wave arrival, respectively.

**Table 3.1**

Data Proposed to be Exchanged at Level 1  
Short Period Instruments
## Long Period Parameters

<table>
<thead>
<tr>
<th>Table 3.2</th>
<th>Data Proposed to be Exchanged at Level 1</th>
<th>Long period and broad-band instruments</th>
</tr>
</thead>
</table>
| **a). Standard Parameters**<br>- All Stations  
(i) **Body-waves**<br>(Vertical and horizontal components)  
1. Arrival time  
2. Maximum amplitude $A_{\text{max}}$<br>$\text{nm}$  
3. Arrival time of $A_{\text{max}}$<br>hour, min, s  
4. Period corresponding to $A_{\text{max}}$  
5. Noise amplitude $A_N$<br>$\text{nm}$  
6. Period corresponding to $A_N$<br>s  
7. Phase identification, amplitudes, arrival times and periods for additional phases, e.g., ScS, etc. (reported when possible)  
(ii) **Surface waves**<br>(Rayleigh-vertical and Love-horizontal)  
8. Arrival time  
9. Maximum amplitude $A_{\text{max}}$<br>$\text{nm}$  
10. Arrival time of $A_{\text{max}}$<br>hour, min, s  
11. Period corresponding to $A_{\text{max}}$  
12. Maximum amplitudes for periods of 10, 20, 30 40 seconds  
13. Arrival times of maximum amplitudes at 10, 20, 30, 40 seconds  
14. Noise amplitude $A_N$<br>$\text{nm}$  
15. Period corresponding to $A_N$<br>s  
16. Association to short period detection (if possible)  
| **b). Additional Standard Parameters - Arrays Only**  
17. Apparent velocity<br>km/s  
18. Epicenter azimuth<br>degrees  
19. Magnitude $M_s$<br> | | |

### Precision of Measurement

<table>
<thead>
<tr>
<th></th>
<th>1 s</th>
<th>0.1 s</th>
<th>0.1 unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Measurement</td>
<td>hour, min, s</td>
<td>nm</td>
<td>hour, min, s</td>
</tr>
<tr>
<td>Volume of Data (Computer Words)</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1 s</th>
<th>0.1 km/s</th>
<th>1 degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

6xn where n is the number of phases
CHAPTER 4
SELECTION OF SEISMOGRAPH STATIONS FOR A GLOBAL NETWORK

Summary

The ad hoc group considers that a global network should comprise around 50 existing or planned seismic observatories, selected in accordance with seismological requirements. It is not known which States would actually make their stations available to a global co-operative system. Therefore, the ad hoc group has chosen to present four examples of possible global networks, each of which is based on different assumptions:

- Network I is based on stations for which information was provided to the ad hoc group (the group requested such information from a number of States)
- Network II includes at least one station from each CCD member State that operates seismograph facilities
- Network III is selected from among all known existing and planned stations according to purely seismological criteria
- Network III (SRO) is similar to Network III, but with each station hypothetically equipped with high-quality instrumentation.

Maps showing the location of the stations in the networks are given in figures 4.1-4.3.

Introduction

There are currently more than 1,000 seismograph stations in operation around the world, and numerous additional installations are being planned. A global network of this size would, however, not be appropriate for seismic verification within a treaty on a comprehensive test ban. The reasons for this are not only the great logistical problems that would be involved in rapid exchange of data for such a large network, but also:

(i) The quality of instrumentation and consistency of reporting procedures are highly variable for existing observatories, and are generally not compatible with the stringent requirements of the envisaged global co-operative system.

(ii) The geographical distribution of existing stations is far from ideal, in particular there are many stations located in the northern hemisphere and there is a substantial overlap of capabilities.

(iii) Previous studies, some of which were discussed in chapter 2, have shown that carefully analysed data from a selected group of relatively few
stations are considerably more effective in a seismic discrimination context than the data reported routinely from a much larger network.

For these reasons the *ad hoc* group considers that a smaller network of stations of high capabilities would be desirable. The procedures and criteria for selecting such a network are described below.

**Ia. Technical description of existing stations of potential interest for the network**

For the purposes of assembling current information on existing and planned seismograph stations throughout the world, the *ad hoc* group of scientific experts requested that each State provide a description of stations on its territory of potential interest for a global network. The information was sought (a) directly of States represented in the *ad hoc* group, (b) formally through the CCD to other CCD member States not participating in the group, and (c) informally through international scientific contacts in a number of other States operating modern seismograph stations. Replies describing stations were received from 17 of the 31 CCD member States, from all of the six non-CCD States participating in the *ad hoc* group at the invitation of the CCD, and from one other State (see table 4.1). Copies of all information on seismograph stations received in this connexion have been retained by the CCD secretariat and interested parties may consult or receive copies of this information on request.

The technical descriptions included the following information that was employed to select subsets of stations for consideration as a global network:

(i) station name, geographical co-ordinates and elevation

(ii) base rock geology in the vicinity of the station

(iii) number and types of seismograph components

(iv) response characteristics of each component

(v) recording medium.

Besides the information obtained through these responses, the *ad hoc* group also had access to additional material on existing and planned seismograph stations. Particular sources were:

- Station descriptions submitted in response to the request contained in the United Nations General Assembly resolution 2604 A (XXIV) of 16 December 1969

- Lists of stations provided by various international earthquake reporting agencies

- Informal working papers prepared by groups of experts and other technical documentation made available to the *ad hoc* group.
A list of stations considered to be of potential interest for a global co-operative network is given in table 4.1. In the following, we will discuss only capabilities for vertical short and long period seismographs. The additional instruments which are of importance for certain identification parameters described in chapter 3, are implicitly assumed to be potentially available to the global network.

4b. Data produced at these stations and present station capabilities

Most seismograph stations contribute data on a routine basis to various earthquake reporting agencies (see section 7a). A number of countries also operate special stations for research on seismological verification and for earthquake prediction programmes. Among the information requested by the ad hoc group was a description of the seismological data produced at each station of potential interest, the methods and time schedule for data communications to recipient agencies, and the time needed for dispatching and storing of original recordings. This information has proved valuable in formulating realistic procedures for data exchange in a global co-operative seismic system (chapter 6).

The ad hoc group also requested available information on average background noise conditions and on statistics about the capability of the station to detect various seismic phases. The median noise level at a given seismographic station is crucial for estimating network capabilities, and the data available here are listed in table 4.1. For most stations these noise estimates were provided from direct observation, or could be derived from information on short and long period detection statistics. For stations planned or under development the noise estimate is made by comparison with an existing station of a similar type and with similar expected noise conditions. Estimates for short period stations for which noise levels are not otherwise known are derived from P-wave detection statistics based on reportings to the International Seismological Centre. For those long period stations for which noise estimates are not otherwise available, the estimates in table 4.1 are based on comparison with a station with known noise characteristics and a similar geographical location.

The noise values listed in table 4.1 are in many cases rough estimates and sometimes are rather arbitrarily defined. However, they are the best estimates of local noise conditions available at the time of writing and are considered adequate for the purposes of estimating network capabilities as described in chapter 5.

4c. Additional data required from existing stations

The goals of international co-operative seismological data exchange for detecting and identifying seismic events would not be entirely served by the data normally dispatched to international earthquake reporting agencies. In most cases these data are neither sufficient, nor available within an appropriately short time delay. The substantial disparities between the desirable and the currently available data from operational stations were already pointed out in chapter 3. The single most important commitment to be made by States participating in international co-operative data exchange will be one which efficiently bridges these gaps.
In chapter 6 specific suggestions are made concerning data, time scales, data communications channels, etc., that meet the envisaged requirements of an international co-operative system. Furthermore, an attempt is made to accommodate as well as possible the present operating practices at stations and national networks that would be contributing to a global co-operative system. Nevertheless, implicit in the descriptions in chapters 3 and 6 are changes in operating practice at most stations that would require the approval of national agencies or governments.

4d. Specification of a global network

In selecting a network for detection, location and identification of seismic events based upon existing and planned seismograph stations, it is desirable to

- arrive at a relatively uniform world-wide geographical distribution of stations
- obtain as homogeneous a network as possible (i.e., consisting of stations of similar capabilities and instrumentation)
- achieve optimum detection and location capabilities, with at least 10-15 stations covering (within their teleseismic zones) any part of the earth
- avoid overlapping capabilities and overloading of the exchange system with redundant data.

The ad hoc group agreed that these principal aims can be achieved with a network of about 50 stations, selected from among those stations known to have the best seismic detection capabilities. Although attempts were made to obtain as much technical information as possible on existing and planned seismograph stations, these attempts were not exhaustive and did not result in a complete description of all stations of interest. Nevertheless, sufficient information is available to assemble groups of stations in networks that will be close to the best achievable with present and planned seismographic facilities.

In order to illustrate the effect of the unavailability, or the non-participation of some stations, four separate networks have been designed. Each is restricted to a total of 50 short period and 50 long period stations and comprises those with the best available seismic wave recording capabilities:

- Network I is composed from among those stations for which information was provided to the ad hoc group of scientific experts (GSE) for potential consideration in a global network (prior to 1 July 1977), and might thus be described as a 'GSE Network'. The selection of stations here is made to provide the best possible coverage with the available stations without any consideration of national boundaries.

- Network II is selected from stations offered to the ad hoc group for potential consideration plus additional stations from other CCD member States; it includes at least one station in each CCD member State that operates seismograph facilities. This might therefore be described as a 'CCD Network'.

-64-
- **Network III** is composed from among all known existing and planned global seismograph stations to achieve the best possible geographical coverage with the best available stations. This might be described as a 'scientific network', and is judged to produce the best seismological results currently achievable for teleseismic detection, location and identification of seismic events.

- **Network III (SRO)** is a hypothetical network. It consists of stations at the same locations as those of Network III, but assumes that modern, high-quality seismic equipment, similar in performance to that of a Seismic Research Observatory (SRO), has been installed at all sites.

A list of all stations used in these networks is given in table 4.1. The stations included in each of the four networks are identified by asterisks. Maps showing the location of the stations in the networks are given in figures 4.1-4.3. Note that some stations are equipped only with short-period or only with long-period instrumentation, while others contain both. Thus the number of sites actually selected in each network will be greater than 50 but less than 100.

The above four networks are examples of selections which might be made for a system of international co-operative measures. The expected capabilities of these networks will be further described in chapter 5.
Table 4.1 List of seismograph stations selected in at least one global network. States represented in the Ad Hoc group (GSE) are marked by asterisks, as are stations for which information was provided to the group. Mean noise levels (SPZ and LPZ) are specified when available, and the network selections are identified by asterisks.

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Figure 4.1 Map showing the location of stations in Network I.
Figure 4.3  Map showing the location of stations in Network III and Network III (SRO).
CHAPTER 5

ESTIMATED CAPABILITY OF THE SPECIFIED GLOBAL SYSTEM

Summary

The topic of this chapter is to estimate, on a theoretical basis, the expected capabilities of Networks I, II, III and III (SRO) defined in chapter 4. The networks have a significantly greater sensitivity in the northern than in the southern hemisphere with regard to detection and location of seismic events as well as obtaining identification parameters. The estimated capabilities are presented in the form of contoured world maps, in figures 5.1 to 5.5. These estimates depend on the confidence level at which a seismic event is considered to be satisfactorily detected and located. The results for the network with the highest capabilities (Network III (SRO)) are summarized by the following examples:

- **Network detection capability for P-waves**: A 90 per cent chance of detecting (at at least four stations) an event of $m_b \geq 3.5$ to 4.2 (or greater) in the northern hemisphere and of $m_b \geq 4.0$ to 4.6 (or greater) in the southern hemisphere.

- **Network location capability**: For a surface event of $m_b = 5.0$, a 95 per cent chance of locating the event epicenter by at least four stations with an error not exceeding 10-20 km in most of the northern hemisphere, and not exceeding 20-50 km in the southern hemisphere.

- **Network detection capability for surface waves**: A 90 per cent chance of detecting (at at least four stations) surface waves from an event of $M_s \geq 3.0$ to 3.4 (or greater) in the northern hemisphere and of $M_s \geq 3.4$ to 3.8 (or greater) in the southern hemisphere.

The estimates for the four networks presented in this chapter are based on a number of explicitly stated, idealized conditions and assumptions: they can only be verified by performing an experiment with actual data over an extended period of time.

No attempt has been made in this study to incorporate probabilistic models for seismic identification based upon a number of signal characteristics. Also, no attempt has been made to assess the effectiveness of individual identification parameters.

The estimated capabilities are based on existing or planned seismographic installations, or as in the case of Network III (SRO), on the hypothetical modernization of the equipment at these installations. These estimated capabilities assume that the data from each station of each network considered are rigorously and diligently analysed according to procedures not all of which are found in common practice at seismographic installations today. It should be noted, however, that improved capabilities in some areas could be achieved (given adequate funds and data analysis) by a network extensively employing proven state-of-the-art seismic array and communications technology. The evaluations should be viewed as an illustration of the possibilities, based on the method of calculation used.
Further improvements in seismic networks or methods of identification will improve the capabilities of the networks presented in this report.

**Introduction**

Because of a maximum in the seismic noise spectrum around six seconds period, seismometers used primarily for the detection of seismic waves are usually designed to respond either to the short period (around one second) band of seismic waves or those of the longer period (around 20 seconds) band (see section 3a). Since the seismic noise at short periods is less than that at longer periods, seismic events are generally most easily detected on short period seismometers. It is recalled that the size of a seismic event is estimated in the two bands as magnitude \( m_b \) based on short period body waves and magnitude \( M_s \) based on long period surface waves.

The capability of a seismometer network to sense that an event has occurred, called the detection capability, is expressed here in terms of \( m_b \), because the short period seismic energy is more easily detected. The location accuracy of seismic events depends on the number of stations in the network that detect the associated signals, so event \( m_b \) is also important when expressing the location capability of a network. The relation of \( m_b \) to \( M_s \) has been found very useful in identifying seismic events. It is therefore possible to give a first estimate of the capability to obtain identification parameters by the detectability of long period surface waves in terms of \( M_s \).

Capability estimates have been made for each of the four networks described in chapter 4; i.e. Networks I, II and III which are based upon existing or planned installations and the hypothetical Network III (SRO).

Although the mathematical model used in these estimation studies is fairly sophisticated, certain idealizing assumptions have been required. For example, the basic model assumes that each station of the network is always supplying uniformly and accurately measured data to the network system based on careful study of the seismic records. The model does not take into account possible equipment failures and errors made when interpreting the data. Another major assumption is that the seismic noise conditions at stations of the networks have been accurately measured and are fairly constant. In reality seismic noise conditions can change frequently and drastically due to interfering seismic signals from separate events as well as unsettled meteorological conditions. It should also be mentioned that the model does not take the full capabilities of seismic array stations into account. The only way to verify the results presented here is to perform an experiment with actual data over an extended period of time.

The main results of these estimates are now summarized. In order to simplify the presentation and at the same time illustrate the differences in capability, only the two extremes among the proposed networks will be discussed here: Network I (of lowest capability) and Network III (SRO) (of highest capability). It should be noted that the improvement of the hypothetical Network III (SRO) over Network III mainly concerns the capability of obtaining identification parameters, and is less significant for detection and location purposes. The reader is referred to appendix III for detailed results on all the networks and for a more complete description of the estimation procedures.
The estimates of detection capability in this section are given in terms of contour lines on world maps, showing the geographical distribution and magnitude of hypothetical seismic events for which there is at least a 90 per cent chance that at least four stations of a given network will detect the event. It is true that a detection at only one station, in some cases, is sufficient to reveal that a seismic event has occurred. However, individual detections by at least four stations are required to locate the event in time and space, though one array could give a very rough location estimate.

The most important factors bearing on the estimates of detection capabilities of a network are:

(i) the geographical distribution of the stations in the network

(ii) the seismic noise level at each station, and

(iii) the factor by which the signal amplitude must exceed the background noise level at individual stations to be recognized with confidence. This is usually stated as a 'signal-to-noise-ratio' and written as S/N.

Since seismic signals generally become smaller with increasing distance from their source, an uneven geographic distribution of stations will usually result in a network detection capability which is uneven and geographically dependent. Furthermore, the ultimate detection capability of a seismic network depends on the level of the background noise which varies from one station to another. The seismic detection capability estimates presented here are, for the most part, based on measurements of noise levels as described in chapter 4. Additional assumptions concerning expected noise levels were required at the stations assumed to be equipped with SRO instrumentation.

In studies of this type assumed values of the signal-to-noise-ratio (S/N) required to declare a detection usually range from factors of 1.5 to 3.0. Routine detection at an S/N of 1.5 requires careful scrutiny of the data and may result in a large number of false detections. Signal detection at an S/N of 3.0 can be made with significantly greater confidence, but at the expense of missing weaker events (see appendix III).

**Network detection capabilities**

Figure 5.1 shows the detection capabilities of Network I and Network III (SRO) based on available noise data and an assumed single station detection threshold equivalent to an S/N of 1.5. Additional assumptions made are given in appendix III. Under these assumptions the interpretation of Figure 5.1 would be that there is a 90 per cent chance that at least four stations of Network I will detect a given seismic event of $m_p 3.8$ or greater in western Europe, of $m_p 4.2$ or greater in most of the northern hemisphere, and of 5.2 or greater from the South Georgia Islands region off the southern coast of South America. In comparison, the detection level of Network III (SRO) varies from $m_p 3.8$ to 4.2 in the northern hemisphere and between $m_p 4.0$ and 4.6 in the southern hemisphere. As could be expected from the distribution of stations, the improvements over Network I are most significant in the southern hemisphere.
Near coastlines and in oceanic areas seismic stations often detect high amplitude signals which originate with seismic events under or near the ocean and propagate efficiently through stratified water of deep oceans. Although sometimes useful in detecting the occurrence of a seismic event, no attempt has been made to include this phenomenon in our studies.

Comparison to current capabilities

The seismological information reported to the International Seismological Centre (ISC) during the four years 1970-1974 was used to compare the detection capabilities estimated here with those experienced under current practice (see appendix III for details). These statistics show that the detection capabilities of the networks considered here under current reporting practices, and with current instrumentation, are significantly less than our estimates of what these networks could achieve under optimum operating conditions. For example, based on four or more stations reporting to the ISC, all three networks report fewer events at the magnitude 4.5 level than at magnitude 4.6 in both the northern and southern hemispheres. Since the number of earthquakes increases with decreasing magnitudes, it is apparent that all three networks, based on the ISC statistics, are missing or not reporting a significant number of events of magnitude 4.5. Our estimates show, in the cases of the three networks mainly made up of existing stations, capability (at the 90 per cent probability level and an S/N of 1.5) to detect events of magnitude 3.8-4.2 in the northern hemisphere. The reason for this discrepancy may partly rest in the idealized assumptions made in the estimation procedures but very likely also reflects the lack of attention paid to small events in current reporting procedures. Clearly, the detection capability envisioned for the proposed global system is not routinely available today.

5b. Estimated global location capability for seismic events

In this section we discuss our estimates of the accuracy with which the various networks described in chapter 4 should locate seismic events. There are several factors which bear on event location accuracy. Larger explosions are generally located with greater accuracy because they are detected by more stations. However, the chief factor limiting our ability to locate very precisely seismic events is the lack of detailed knowledge of the time it takes seismic waves to propagate along specific paths through the earth. By making realistic assumptions about the detection capability of individual stations, as was done in section 5a, and about the variation of seismic wave propagation times along different paths, it is possible to estimate the achievable location accuracy for an event of a given magnitude as detected by a specified network.

There are four unknown quantities associated with each seismic event which must be specified for its proper location in time and space. These are the time of origin, latitude, longitude and depth. The achievable accuracy of the last three is usually given in terms of the dimensions of an ellipsoid and thus the ability of a network to locate an event occurring at the earth's surface is given in terms of the orientation and dimensions of an ellipse. For simplicity, and since we usually want an indication of the maximum error that may be associated with the location procedure, location accuracies are expressed using half the maximum dimension of the surface error ellipse. Thus, based on assumptions of network detection capability, the earth's seismic propagation characteristics, and the occurrence of an event at a given magnitude and location, estimates are computed of the maximum dimension of an area within which there is a high probability
(e.g. a 95 per cent chance) of the network locating the event. Holding all other factors constant, the assumed event location is systematically varied over the earth, resulting in a world map on which the maximum anticipated location errors associated with an event of a given magnitude may be contoured. This procedure gives an estimate of the location capability of a seismic network.

**Network location capabilities**

Figure 5.2 shows the estimated capabilities of Network I and Network III (SRO) to locate a seismic event assumed to occur at the earth's surface with a magnitude \( m_L \) equal to 5.0. It should be interpreted as follows: there is at least a 95 per cent chance that the maximum error to occur, when locating surface seismic events of magnitude 5.0, will be less than or equal to the number of kilometers contoured in figure 5.2. Under these conditions the figure shows that for Network I the maximum anticipated error will be less than 20 km in Europe and most of Asia, and less than 30 km in most of North America. Errors greater than 100 km must be anticipated in parts of the southern hemisphere. In comparison, Network III (SRO) has an increased world-wide location capability because of a more even distribution of stations. For example, the maximum anticipated errors with this network are 40 km off the west coast of South America and 50 km off the north and south coasts of eastern Australia.

**Depth determination**

A procedure similar to that used above in estimating lateral location accuracies can be used in estimating network accuracies in depth determination. Based on the restrictive assumption that only times of the arrival of the initial seismic energy at each station are used, an estimate of the event depth determination capabilities of the various networks has been made, and these are included in appendix III. These estimates indicate, for example, that there is a 95 per cent chance that a given event of magnitude 5.0 occurring at the surface will be located by Network I within 50 km of the surface over much of Europe, Asia and North America and within 100 km or greater over most of the southern hemisphere. Network III, because of its more even distribution of stations, has greater depth determination accuracy in some regions of the southern hemisphere.

The matter of depth determination points to a problem in our procedures used to estimate the capability of seismic networks to locate seismic events. The difference in time between the arrival of the initial seismic energy and the energy that reflects from the earth's surface above the seismic event is proportional to the depth of the event. When measured, this difference provides a much better estimate of depth than initial arrival times alone. However, the factors involved in estimating the capability to measure this delay are too numerous to include in our modelling procedures. Other specialized techniques can be used to improve event location, such as using a nearby event of known location for control or calibration. Our models for estimating network location capabilities are based on only the most straightforward, widely accepted and most widely applicable procedures and do not include specialized techniques and practices which may, under certain circumstances, give significantly better results.

**5c. Estimated global capability to obtain identification parameters for seismic events**

The magnitude criterion \( (M_s : m_b) \) is widely accepted as a useful discriminant
between earthquakes and underground explosions (see chapter 3). In section 5a we discussed the estimated capability, in terms of \( m_b \), of the various networks to detect short period energy from seismic events. In this section we shall present the results of similar analytical procedures applied to estimating the capability of networks, in terms of \( M_s \), to detect long period seismic energy, i.e., surface waves.

**Surface wave detection capabilities**

Figure 5.3 gives the estimate of the long period detection capabilities of Network I and Network III (SRO). The contours of the figure represent event magnitude (\( M_s \)) at which there is a 90 per cent chance that at least four stations would detect long period waves with an S/N of 2.0. It is seen that at this probability level, Network I will detect a seismic event of surface wave magnitude \( M_s \approx 3.2 \) to 3.6 or greater in most of the northern hemisphere and events of \( M_s \geq 4.0 \) or greater world-wide. Network III (SRO) on the other hand, will show significantly better capabilities, ranging from about \( M_s \approx 3.0 \) to 3.4 over most of the northern hemisphere and from \( M_s \approx 3.4 \) to 3.8 over the southern hemisphere.

Some members of the ad hoc group felt that measurement of \( T_s \) at four stations, properly distributed in azimuth, is required to give a stable measurement of the long period energy or \( M_s \). In the opinion of others, measurement of \( M_s \) at two stations is sufficient, especially if the actual noise levels at stations with no surface wave detections are utilized. Figure 5.4 for Network I is analogous to 5.3 except that detections at only two stations and an S/N of 3.0 are required. The figure indicates that relaxing the detection criteria from four to two stations while increasing the S/N to 3.0 improves the estimated capability of the network slightly. If the S/N is kept at 2.0, the resulting improvement in surface wave detectability, based on two stations, is about 0.2 \( M_s \) units world-wide.

**Detection conditions suitable for obtaining short period identification parameters**

Certain short period measurements, other than magnitude, have been found useful in the identification of seismic source type. Although there is no general agreement on how best to compute short period identification parameters, most of the methods suggested require that the signal be recorded in digital form. It is also generally agreed that the short period identification criteria demand a larger S/N than required for simple detection. In order to estimate what might be the world-wide capability of Network III (SRO) to obtain short period identification parameters, an analysis was carried out assuming that each station can compute such parameters whenever it records a signal of sufficient S/N. In this analysis we did not consider stations within 2,200 km of a source location because of the complicated seismic propagation paths to stations within this distance range. Otherwise, an S/N of 3.0 was assumed to be necessary. Under these assumptions, figure 5.5 shows that there is a 90 per cent chance that Network III (SRO) can provide short period identification information at at least four stations for events of \( m_b \approx 4.4 \) to 4.6 or greater in the northern hemisphere and \( m_b \approx 4.6 \) to 5.0 or greater in the southern hemisphere.

The ad hoc group recognizes that the problem of assessing the sensitivity of a network to obtain short period identification parameters is difficult. The contours shown in figure 5.5 resulted from an attempt to make an initial estimate of
the capability of the hypothetical Network III (SRO), using criteria considered to be generally acceptable.

Discussion

The network capability estimates are dependent upon the values assigned to an elaborate set of parameters. Of particular interest is the probability level assigned to a certain capability: here we have chosen to work with the levels that are traditionally used in studies of this kind, i.e., a 90 per cent level for detection capabilities and a 95 per cent level for location accuracies. It might also be of interest, e.g., to determine the magnitude at which there is a 10 per cent chance that signals from an event will be detected. Clearly, lowering the probability from 90 per cent to 10 per cent will produce lower magnitudes for the corresponding contour map; the differences for the capability maps shown here will typically be on the order of 0.2-0.3 magnitude units.

The estimates made of the capabilities to obtain identification parameters should be considered as examples of what can be achieved, using individual signal characteristics. The probability methods of identification on the basis of a number of characteristics, elaborated in the USSR, Sweden, United Kingdom, Canada, Norway and other countries, have not been examined, since these methods have been tested only in the above-mentioned countries and have not yet been accepted as a part of international practice.

In conclusion, it is emphasized that the estimates of this chapter concern the capability of various networks to detect and measure certain parameters found useful in the identification of seismic events and do not include any attempt to assess the effectiveness of these parameters or how they should be combined and weighed in identification schemes.
Figure 5.1 Estimated short period detection capability of Network I (top) and Network III(SRO) (bottom). The estimates are in terms of $m_b$ based on a 90% chance of detection at at least four stations with an S/N of 1.5.
Figure 5.2 Estimated capabilities of Network I (top) and Network III(SRO) (bottom) to locate a surface event of $m_b=5.0$. The contours represent length (in km) of semi-major axis of 95% confidence ellipse.
Figure 5.3 Estimated long period detection capability of Network I (top) and Network III(SRO) (bottom). The estimates are in terms of $N_S$ based on a 90% chance of detection at at least four stations with an S/N of 2.0.
Figure 5.4 Same as Figure 5.3 (top part), except that detection is required at only two stations with an S/N of 3.0.

Figure 5.5 Estimated short period detection capability of Network III (SRO) in terms of $m_b$ based on a 90% chance of detection at at least four stations at distances greater than 2200 km and with an S/N of 3.0. These detection conditions are considered suitable for obtaining short period identification parameters.
CHAPTER 6
DATA EXCHANGE BETWEEN SELECTED STATIONS AND INTERNATIONAL DATA CENTRES

Summary

The ad hoc group has reviewed and assessed several possible media for seismic data exchange at Levels 1 and 2 (see section 3b). The consensus of the group is:

- For Level 1 data (basic signal parameters) usage of the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO) is recommended because of its global availability, proven operation and low cost.

- For Level 2 data (requested waveforms) which are generally more voluminous and not so critically dependent on fast communication, several solutions might be employed. Digital transmission (e.g., via WMO/GTS) should be used when possible; otherwise, telecopying of seismograms is recommended in preference to using mail services.

Consideration has also been given to the time delays that would be involved in the data exchange. The ad hoc group considers that realistic goals in this respect are:

- Maximum 3-5 days delay in the reporting and processing of Level 1 data,

- Maximum 4-6 weeks delay (after request) in obtaining Level 2 data. As operational experience is gained, this delay should be considerably reduced.

The use of the GTS for transmission of seismic data in general, has already been authorized by the WMO. According to information available to the ad hoc group, the excess capacity of the GTS is sufficient to handle the expected load from the proposed data exchange.

In order to use the WMO/GTS for data exchange within the global network it will be necessary to obtain an official agreement through the appropriate international organizations.

Introduction

To establish adequate provisions for the multilateral exchange of seismic data is one of the most important aspects of the international co-operative system discussed by the ad hoc group. Besides handling the large volumes of data and adhering to the strict requirements of transmission quality, it is also vitally important to maintain the timeliness of the exchange procedures. In this respect, it should be kept in mind that existing co-operative seismic systems, although exchanging far less data than required in the present context, operate with response times ranging from several weeks to more than a year. Such time delays would probably not be acceptable to most States supporting a network for international data exchange in the context of a nuclear test ban. The discussion
in the following sections addresses the choice of data exchange media, transmission formats and the expected load on the transmission channels.

6a. Description of existing data exchange facilities

The Global Telecommunications System (GTS)

The Global Telecommunications System (GTS) is jointly operated and maintained by the 143 member States of the World Meteorological Organization (WMO). It is a world-wide telex communications network established to collect, exchange and distribute mainly meteorological data between national, regional and world meteorological centres. The system consists of:

- A Main Trunk Circuit, which connects World Meteorological Centres with Regional Telecommunications Hubs;
- Regional Telecommunications Networks, providing further connexion to National Meteorological Centres;
- National Telecommunications Networks, which supply the linkage to national meteorological stations.

A schematic diagram of the GTS is shown in figure 6.1.

Transmission of seismic data through GTS

In the fifth session of the Commission for Synoptic Meteorology (1970), note was taken of the resolution transmitted to the Secretary-General of WMO from the President of the International Union of Geodesy and Geophysics which urges the WMO to facilitate arrangements for the utilization of meteorological circuits for the transmission of seismic data. Later that same year, at the request of the Commission, the twenty-second session of the Executive Committee of the WMO discussed this problem and agreed in principle that the GTS be used for the transmission of environmental geophysical information, which includes seismic data and information. At the present time about 10 countries are using the GTS to report seismic data with a total daily volume not exceeding 800 characters.

As an example, the Pacific countries exchange earthquake parameters, tide gauge data and tsunami information through the GTS. Seismic data from the Japan Meteorological Agency are also transmitted routinely to the National Earthquake Information Center of the United States Geological Survey through the GTS. The following shows as an example a message from Matsushiro to United States Geological Survey describing one seismic event.

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Explanation: SE=seismic data, JP=Japan, 2C=regional and interregional distribution, R=near Japan, T=centre name, D=place
In practice, the transmission of seismic data through the GTS is arranged by the national meteorological communication centres in accordance with 'Manual on the Global Telecommunication System' (WMO-No 386-1974). The seismic data are transmitted by the UMO/GTS without heading to specify addressee. For instance, the example shown does not carry the addressee's name, but a numerical code "20", to indicate that the message should be distributed throughout regional and in interregional centres. Any station or organization that has made arrangements with the relaying communication centres en route would then receive the message. This is a very flexible arrangement - an important consideration for the ad hoc group.

At present seismological data transmissions are much more limited in volume and occur less frequently than those of meteorological data. For this reason, the operational instructions for handling seismic data are sometimes not adequately attended to at the relaying centres. This had been known to cause occasional loss of seismic data in the past, but can be resolved through adequate training of personnel.

As long as the seismic data do not claim a high priority within the GTS, there is ample space available in this communications system to handle the volume of transmission expected for the global data exchange described in this document.

The ARPANET Communications Network

The ARPANET is an operational, intercomputer data transmission network operated by the United States. The interest of the ARPANET to the work of the ad hoc group lies in:

- its application of advanced computer communications technology and high capacity transmission channels;

- its ability to provide linkage between entirely different computers by use of specially designed front-end processors;

- its proven operational capabilities in transmitting seismic data on a large-scale basis.

Presently the ARPANET is being used to transfer data between various seismic verification research activities, most of which are sponsored by the United States. Internationally, the ARPANET connects seismological data centres in the United States, the United Kingdom and Norway.

Since the ARPANET is a United States Government project, it was not discussed by the ad hoc group as a potential medium of data exchange for the global network. However, should the decision be made to establish a special purpose communications system for the global network, the experience gained from the ARPANET will be of great value.

Other computer networks

In the near future there will be established other international general purpose distributed computer networks besides ARPANET. On a national basis some networks in Europe are already operational, e.g., in France and the Federal Republic of Germany. Other countries are providing data network services on an experimental scale. These developments will assume their full importance when common international network standards are introduced. The requirements for such standards
have been set up by the CCITT (Committee Consultative Internationale de Telegraphe et Telephone) and its recommendations are usually followed by the national telecommunications administrations. Within such networks rapid and reliable transmission of large volumes of seismic data may be achieved. However, global availability of such facilities cannot be expected for a number of years.

Commercial telex and mail

Commercial telex and mail are the most common methods for exchanging seismic data. Telex is well adapted to rapid exchange of limited data volumes, such as Level 1 data. For larger volumes, such as seismograms or magnetic tape recordings (Level 2), air or surface mail is usually the most convenient. The advantages of these services are of course their global availability and relatively low cost. Regardless of the system actually chosen for data exchange for the global network, telex and mail will be important for back-up and supplementary purposes.

Telexcopy systems

For the rapid exchange of seismograms, telecopying is a viable alternative to mail or various digital transmission schemes. Within such a system both analog and digital recording seismograph stations can participate. Some obvious advantages of this system are its technical simplicity, making use of standard telephone lines, and its modest costs. Several organizations, e.g., in Sweden, the United Kingdom and the Federal Republic of Germany, have tested such equipment for the exchange of seismograms.

The resolution of a telecopied image is not sufficient to preserve the total information of digital seismograms, but it is adequate to reproduce analog data and to identify the most important features of digital waveforms. An agreement on common formats will be necessary to facilitate digitizing of the received data. Despite its relatively low resolution, telecopying is a realistic and practical way to exchange data for the purposes envisaged by the ad hoc group.

6b. Data to be exchanged

The desirable data recommended by the ad hoc group for the global co-operative system were specified in chapter 3. It was recognized that the number and types of parameters reported will differ from station to station because of the lack of uniformity in the existing network of seismographic installations. However, it is essential that each station follows a consistent and well defined practice for those parameters it does report.

Data at Level 1 (transmitted regularly for all events)

In order to assess the total expected volume of Level 1 data, reference is made to the previously shown tables 3.1 and 3.2. The volume of data for a P-signal recorded on a short period vertical seismograph would typically be about 20 to 30 computer words. Similarly, the long period data of one event would require about 30 words if S-waves and Rayleigh waves were reported. Reduction of these numbers is possible by optimal coding techniques. The number of events registered at any given station would vary as a function of seismicity, noise level and station sensitivity, and could range from less than 10 to more than 50 during a single day.
Data at Level 2 (provided only on request)

Level 2 data are essentially waveforms but could in certain cases also comprise results from special analyses of recorded signals, e.g., at arrays. Typical volumes of the digital data would be:

- 60 seconds of short period vertical component P-wave data sampled 20 times a second, i.e., a total of 1,200 computer words;
- 20 minutes of a three-component long period recordings sampled once a second, i.e., 3,600 words total.

The Level 2 data would presumably be requested only for a few events per month. Therefore, the above data volume would not be excessive for transmission over digital channels. However, capabilities for transmitting analog data must also be provided in the data exchange system.

6c. Time scale, data format and data channels to be used for the global co-operative system

Time scale

There is a consensus among the members of the ad hoc group that Level 1 data must be reported to the international centres and analysed as quickly as possible. Since most seismological observatories operate on a daily cycle, daily transmission of the standard Level 1 parameters would be a natural choice. To allow for possible delays due to, e.g., the routing of information through national data centres, a maximum delay of 3-5 days should be established as a norm. For some of the specialized parameters in tables 3.1 and 3.2 some stations might prefer, for practical reasons, to transmit these data to the international centres on a weekly or monthly basis, or possibly only on request.

For Level 2 data, no particular time limit can be established, since these data could in principle be requested from individual countries long after the seismic event took place. One should, however, take into consideration that some stations may retain their complete data files only for a limited period (e.g., 12 months). The individual stations should respond promptly to data requests. In the opinion of the ad hoc group, the "worse case" waiting time for complete data files after a request had been initiated should not exceed 4-6 weeks, and efforts should be made to achieve a much shorter response time as operational experience is gained.

Data formats

For Level 1 data the recommendation of the ad hoc group is to employ the Earthquake Data Telegraphic Format, developed by the United States Geological Survey. Advantages of this format are:

- It is designed for telex transmission and is therefore acceptable to the WHO/GTS as well as to commercial telex;
- It has already been in use for a number of years for seismic data transmission;
It is easily adaptable to extensions of the data fields, which would be necessary in view of the additional identification parameters to be transmitted.

The formats for Level 2 data will depend on the transmission channels actually selected, and are not discussed in detail here.

**Data channels**

The ad hoc group considers that the Global Telecommunications System (GTS) of the WMO is well suited for the exchange of data in a global co-operative seismic network. According to information available to the ad hoc group, the GTS has excess capacity sufficient to handle the expected load. As an example, with reasonably efficient coding, 100 characters would be sufficient to transmit the Level 1 data for one event. If we assume that each seismic station records 50 events per day (a number that is well above average), the total number of characters is 5,000 per station, or 250,000 for the 50-station network. This data volume can be handled by a standard GTS circuit in less than 1/2 hour, and is well below the expected reserve capacity of the lines.

The response time for Level 2 data is less critical than for the data at Level 1. Moreover, seismograms from many stations would be in analog form, and hence cannot be transmitted over digital circuits like the GTS. The ad hoc group therefore recommends that the most practical way to exchange Level 2 data should be decided on an individual basis for each separate station and that efforts should be made to use digital transmission (e.g., via the GTS) and telecopying in preference to mailing magnetic tapes and seismograms.
CHAPTER 7

INTERNATIONAL CENTRES FOR COLLECTION, PROCESSING AND EXCHANGE OF SEISMIC DATA

Summary

The Ad Hoc group considers that special international data centres should be established for the global network. In order to achieve a reliability acceptable to all, it is proposed that more than one standardized international centre be established, thereby following practice established inter alia by the World Meteorological Organization (WMO), having communication centres in Moscow, Washington, D.C., and Melbourne. In connexion with the use of WMO/GTS for data exchange it is desirable, for technical and other reasons, to locate International Data Centres in the places where main WMO communications centres are situated, such as in Moscow (USSR) and Washington, D.C. (USA). The Group recognizes that it would be desirable and technically feasible to establish International Data Centres in other places as well, e.g. in the southern hemisphere.

The main tasks of the international centres will be:

(i) to receive data of Levels 1 and 2 from the world network of seismic stations via the authorized Government facility of each State

(ii) to apply agreed analysis procedures to available data for the estimation of the origin time, location, magnitude and depth of seismic events

(iii) to associate reported identification parameters with these events

(iv) to distribute, in accordance with defined procedures and without interpretation of identification parameters, compilations of the complete results of these analyses

(v) to act as an archive for reported data and results of analysis on those data.

The international centres should be equipped with equivalent hardware and software. Each centre would perform equivalent processing of all Level 1 data. If requested, the centres would ask for and forward Level 2 data.

Introduction

The purpose of this chapter is to examine the various tasks related to collecting, processing and storing the data of an international seismic data exchange system and to evaluate the role of international data centres in this connexion.

First it is worth asking why "centres" of any kind should be necessary. The answer lies in the benefits of combining data from a network of stations.
For example, the recordings from just one "standard" station give a seismologist only a very rough idea of when and where a seismic event occurred. Even the much greater capabilities of arrays of seismometers do not provide very accurate locations. A network of stations, with or without arrays, gives significantly improved results when the individual data of each station are combined for the purpose of estimating the event location and origin time. The procedures are outlined in section 3a. The places where the data are brought together for this purpose are called seismic data centres.

Accurate source location is a prerequisite for proper identification of seismic events. Therefore one or more data centres are mandatory to the successful operation of a global network. Other functions related to the collection and dissemination of seismological data can also be handled by data centres. In principle, one such centre for the global network suffices; in practice the problems of international data exchange make it desirable to establish more than one. The primary reason is the additional security and back-up possibilities which several data centres provide. In addition, the exchange of data and dissemination of processed information are performed more efficiently when more than one data centre is available. Moreover, current practice in the international exchange of meteorological and geophysical information has clearly demonstrated the benefits of having a number of international data centres.

7a. Description of some existing data centres

In the following a sample of existing seismological data centres are briefly discussed in order to demonstrate the variety which is already established in support of seismological research. A more complete description of these data centres has been included in appendix IV of this report. Clearly, the experience gained from years of routine operation of seismological data centres will be instrumental in establishing guidelines for similar centres in the context of global co-operative data exchange.

There is one seismological data centre which commands a broad and formal basis of international support and is staffed internationally. This is the International Seismological Centre (ISC) which is now located in the United Kingdom. This is the descendent of the International Seismological Summary, which began publishing listings of principal earthquake data in 1911. Its task of processing epicentral data, transmitted to it from any station in the world which wishes to contribute, is financially supported by 33 national agencies in 32 countries (as of September 1977).

The operation of the Centre follows guidelines laid down by representatives from each contributing organization, the Governing Council. The Council has required a delay of about two years between the time of earthquake occurrence and its listing in ISC publications in order to give all stations the opportunity to contribute. None the less, in 1976 the Centre demonstrated experimentally that it is also technically capable of providing a fast epicentre and magnitude service, should this be required.

Due to its global character, the ISC receives data in a variety of formats and from stations that are far from standardized with respect to equipment and operating practices. A significant part of the effort at the ISC is therefore
devoted to data preparation and reformatting. The estimates provided by the ISC on epicenter, depth and origin times of seismic events are probably the most accurate and certainly the most complete that are available today. Body-wave magnitudes (m_b) are computed for most events, while surface-wave magnitudes (M_s) are available only in few cases because surface-wave amplitude data are not generally reported from individual stations.

There are two other centres of special international recognition: The National Earthquake Information Service (NEIS) of the United States, which provides the Preliminary Determination of Epicentres service and the European-Mediterranean Seismological Centre (EMSC), established under the responsibility of the European Seismological Commission. The NEIS and EMSC differ from the ISC in having a faster response time (normally a few weeks) and in that they do not command the formal world-wide financial support enjoyed by the ISC. Nevertheless they have strong international links. Supported by the United States and (principally) France, respectively, they provide a fast epicentre service to any contributor - world-wide epicentres in the case of the NEIS and, as its name implies, European and Mediterranean epicentres in the case of the EMSC. It is noteworthy in the present context that these two centres have developed procedures for accelerated response in the form of provisional epicentral determination within a few hours after great, potentially destructive earthquakes. Such capabilities have also been established at other existing data centres, and are based on the rapid availability of event detection data via telex from selected seismograph stations.

Another centre described in more detail in appendix IV is the Seismic Data Analysis Center (SDAC) in the United States. It differs from the first three in that it does not provide an epicentre service. It receives, organizes and stores digital seismograms recorded at technically advanced stations distributed around the world, offers distribution services for these recordings and maintains a broadly based national research effort on problems of discriminating between earthquakes and explosions, as well as on data management processing and analysis techniques in relation to test-ban verification.

The Blacknest Data Analysis Centre located in the United Kingdom has objectives identical with SDAC, albeit on a smaller scale. However, in order to provide for the possibility of making a contribution to verification procedures, it was decided in 1974 to investigate this problem using four seismic arrays and a few United Kingdom standard stations as an experimental network. The experience thus gained is described in appendix IV and may be useful for planning an international trial of this kind.

There are several other well-established data centres for seismology. Those of Canada, South America (CERESIS), Japan, New Zealand, the Nordic countries and USSR, in particular, are well known. However, most countries (many of them Member States) which are subject to high seismic risk, have established local seismic data centres for social as well as scientific reasons; India, Pakistan and Bulgaria are special examples. In some seismic zones new Regional Data Centres are being established; those developing in South-East Asia and Central America are examples. Because of social benefits which follow fast and accurate information services on catastrophic earthquakes, there is a general move towards developing fast responses within national networks. This tendency is favourable for the purposes of a CTB.
The purpose of this and the following sections is to define and examine the special tasks which the requirements of an international seismic data exchange system might impose.

An international seismic data exchange system is a formalized method of exchanging seismic data between States for the purpose of detecting and locating seismic events and of facilitating the identification of seismic events by individual States, parties to the treaty on a comprehensive test ban. Such a system consists of individual seismic stations and international data centres all linked by a fast and reliable communications network.

The seismic stations, consisting of short and long period three-component seismometers or an array of seismometers with associated processing equipment, provide the Levels 1 and 2 data detailed in chapter 3 to the exchange system. In this context individual stations of a country's network would normally provide the seismic data to international centres through a government-authorized facility. States not wishing to establish a special facility could, however, authorize their stations to transmit data directly to international centres.

These government-authorized data distribution facilities would be under the complete control of the State within which they are located. They act with respect to the international data exchange system as the responsible and primary point of data distribution for seismic data recorded in that State. Except for internationally agreed types and formats of data to be exchanged, the operations and analytic procedures used would be determined by the State in which the facility rests. Such a facility is here so described only in the context of the international data exchange system and has in this respect no implied internal authority or responsibility concerning the verification of any test ban agreement other than data exchange. At the discretion of the Government in question, they could none the less be given authority and responsibilities in addition to data exchange.

In principle, data distribution facilities authorized by Governments could exchange, between themselves, all the data described in chapter 3 for locating and identifying seismic events. In practice, the Ad Hoc group considers it more desirable to introduce international centres in order to assure, to all participants, the high standards of reliability, quality and speed appropriate to the special problems of controlling a test ban by national technical means. International centres would have data collection, storage and analysis facilities with procedures controlled by agreement of participants in the international data exchange system. The primary roles of an international center would be:

(i) to receive data of Levels 1 and 2 from the world network of seismic stations via the authorized Government facility of each State

(ii) to apply agreed analysis procedures to available data for the estimation of the origin time, location, magnitude and depth of seismic events
(iii) to associate reported identification parameters with these events.

(iv) to distribute, in accordance with defined procedures and without interpretation of identification parameters, compilations of the complete results of these analyses.

(v) to act as an archive for reported data and results of analysis on those data.

The Ad Hoc group considers that there should be more than one international centre equipped with equivalent hardware and software. Each centre would be required to provide free and easy access to all facilities designated "international".

7c. Procedures to be used for data exchange and dissemination

The elements from which a data exchange system can be constructed have now been described. There are a number of ways in which these elements may combine, each having certain advantages and disadvantages.

The possibility of direct exchange of data between States has already been mentioned. Another possibility would involve the establishment of a single international centre through which all exchanges of data would take place.

A procedure which is now used in research practice involves direct exchanges between the centres of individual countries with, at the same time, data passing to an international centre (e.g., the ISC) only for estimating epicentres and for storage. By adopting such a procedure, the international centre would be relieved of the burden of responding to requests from individual countries and could devote its resources to the primary task of producing lists of epicentres and associated identification parameters.

The procedure favored by the Ad Hoc group is a variant of the above. In order to achieve a reliability acceptable to all, it is proposed that more than one standardized international centre be established, thereby following practice established inter alia by the World Meteorological Organization (WMO), having communication centres in Moscow, Washington, D.C., and Melbourne. In connexion with the use of WMO/GTS for data exchange it is desirable, for technical and other reasons, to locate International Data Centres in the places where main WMO communications centres are situated, such as in Moscow (USSR) and Washington, D.C. (USA). The Group recognizes that it would be desirable and technically feasible to establish International Data Centres in other places as well, e.g., in the southern hemisphere.

In the proposed scheme, all Level 1 data would be routed to all international centres via each country's authorized distribution point. Each international centre would respond with identically processed lists of epicentres and associated identification parameters. If requested, the centres would ask for and forward Level 2 data. Airmail and telecopying methods for transmission have been suggested for this purpose (see chapter 6), although there are no fast response procedures in common use in seismology at this level. They remain to be studied and agreed.

The main elements involved in this procedure are illustrated graphically in figure 7.1.
Purpose of State Facility:

1) Sends Level 1 data
2) Receives epicenters and associated identification parameters
3) Sends and receives Level 2 data on request.

A single station when officially authorized has similar commitments.

Figure 7.1 Schematic diagram of the main elements involved in data exchange between stations and international data centers.
CHAPTER 8
EQUIPMENT AND ESTIMATED COSTS TO ESTABLISH AND OPERATE THE SPECIFIED SYSTEM

Summary

The three major components of the proposed co-operative system are (i) the seismograph stations, (ii) the data communications facilities and (iii) the international data centres:

(i) For the equipment at seismograph stations, two degrees of sophistication have been considered:

- The minimum equipment required for participation comprises standard instrumentation that is already available at most stations under consideration.

- The desirable equipment at each station would be modern, high-quality instrumentation which would ensure data acquisition in numerical form.

(ii) The requirements for data communications consist of a telex terminal and communication lines to interface the World Meteorological Organization (WMO) network and of equipment for exchanging seismograms.

(iii) The requirements at an international data centre consist of a modern, medium-size computer facility with associated equipment, including two small special purpose computers for data communications. Special software for the communications and data analysis tasks will be needed.

The expected cost and manpower to establish and operate the system cannot be given in detail, due in part to the great variations of cost levels between countries. Order of magnitude estimates are included for purposes of illustration, and are summarized in table 8.2.

Introduction

The purpose of this chapter is to enable the reader to assess, very approximately, the cost of participating in a system of international seismic data exchange. The cost of operating existing seismograph stations varies greatly from one country to another, and so will the cost of modifying existing stations and current operating practices to meet the requirements of the specified international system. Moreover, the load on manpower, communications and data processing services will increase with increasing station capabilities. For these reasons, the standard equipment of seismograph stations, the desirable technical modifications and the required extra manpower are described in general terms only. Approximate costs based on existing installations are included for
purposes of illustration and should only be considered order of magnitude estimates. Because the cost of manpower differs greatly between countries, no attempt is made to estimate the costs of any additional personnel that would be required.

8a. Equipment and estimated costs to establish and operate seismograph stations

Minimum equipment

The minimum equipment at a station of the global network should comprise:

(i) one three-component set of short-period seismographs (peak response at approximately 1 second) and one three-component set of long-period seismographs (peak response at approximately 20 seconds). These instruments need not be located at the same site

(ii) timing and calibration equipment

(iii) a visual recording system (pen or photographic)

(iv) copying equipment.

These requirements are already met by most of the stations considered for the network. Because the stations selected in chapter 4 already operate or are planned to operate in support of seismological research programmes, there will be little additional costs for installation and maintenance of the equipment. For our stated purposes, however, station operation procedures must be much more efficient than is common seismological practice. This involves daily maintenance, daily detailed reading of all seismograms and daily preparation of telegraphic reports. It is estimated that at least one extra full-time operator will be needed at each station in order to comply with these requirements.

Some improvements to existing standard stations are possible to achieve at a relatively low cost. Modernizing the recording equipment, for example, by introducing variable band-pass filters would enhance detection capabilities. Level 2 data (waveforms) would as a minimum be supplied as seismogram copies but should preferably be available in digital form. Equipment suitable to convert analog photographic recordings to digital form on magnetic tape costs approximately $US 40,000.

Desirable equipment

Seismological observatories equipped and operated to ensure the highest operational efficiency might be established either to replace existing installations or to supplement the proposed network with additional seismic stations of high quality. Ultimately, all stations of the network should conform to such standards. The equipment proposed here (see table 8.1) is similar to that of the United States-designed Seismic Research Observatories (SROs) or of the Grafenberg (GRF) broad-band station in the Federal Republic of Germany (figure 8.1):

- a three-component broad-band seismometer installed in a vault or borehole,
- equipment for converting the analog seismic signals to digital (gain ranged) form,
- two magnetic tape transports for digital data recording,
- a set of pen recorders for continuous display of signals in different frequency bands,
- a highly accurate timing system,
- a small computer for over-all control of station functions, including calibration, and for automatic detection of seismic events.

Cost estimates for such equipment vary from $US 100,000 to $US 200,000 depending on the quantity of instruments and type of data transmission facilities. Installation costs, including drilling, connexion to power lines, building, etc., are significantly different from country to country, a rough estimate is $US 100,000.

The main costs for operating and maintaining a modern, technically complex digital installation like the SRO-stations come from the need for external technical support, this amounts to about $US 20,000 annually. If a station were maintained by an on-site qualified technician with easy access to spare parts, the estimated costs for maintenance would be reduced to about $US 10,000 p.a.

§b. Equipment and estimated costs for transmitting data between stations and data centres

The Global Telecommunications System co-ordinated by the World Meteorological Organization (GTS/WMO) has been recommended (chap. 6) as the only available world-wide installation to accommodate rapid exchange of seismic detection and identification data. The WMO has already authorized the use of GTS to transmit limited seismic data without any additional costs. It will, however, be necessary for each State to make its own arrangements with the local GTS terminals.

For Level 1 data, each observatory would use the WMO/GTS and would therefore need a telex terminal to gain access to this communication system. Rental costs for a telex terminal are about $1,000 p.a. In some countries, the envisaged government-authorized distribution facility for seismic data (chap. 7) might be located at a distance from the GTS terminal facilities. These countries would have additional costs associated with a local communication link to the GTS. Countries with many and widespread stations contributing to the global system would also incur additional costs, owing to the increase in the volume of data and the great distances to transmit these data.

Level 2 data (waveforms) can as a minimum be exchanged by air mail. The ad hoc group has recommended (chap. 6) the use of telecopying for data exchange at Level 2, and in many areas this facility can be obtained via standard telephone lines. Purchase and installation of telecopying equipment come to about $US 4,000.
Level 2 data in digital form could be transmitted telegraphically, in limited quantities, by means of paper-tape input. For larger volumes, a computer interface to the telex line would be desirable. Such interface equipment, which costs about $US 10,000, would also facilitate the exchange of Level 1 data.

6c. Equipment and estimated costs to establish and operate international data centres

International data centres for the proposed global network need facilities for extensive telecommunications and for processing, analysis and storage of data. Modern computer and communications equipment must therefore be installed in such centres. As discussed in chapter 7, the ad hoc group sees the need for more than one international data centre in the global co-operative system. It is possible that these centres could to some extent build upon existing facilities, thereby reducing the cost for their establishment and operation. However, in view of many uncertain factors in this respect, the discussion here will only address the equipment and cost necessary to establish and operate new data centres appropriate for the global co-operative system.

Telecommunication can be handled by use of two small computers, one dealing with the regular communications traffic, the other having mainly back-up functions. The main computer of the data centre could be configured as follows (figure 8.2):

- a central processor with sufficient memory (at least 100,000 computer words) and adequate computing speed (at least 1 million instructions per second)
- mass storage on disk for data and programs (capacity of at least 50 million computer words)
- four magnetic tape transports for digital recording
- three interactive terminals
- access to a large back-up computer (either stand-by or remote) in case of system breakdown.

A central computer of the above specifications would cost about $US 300,000 and the telecommunication equipment would amount to about $US 100,000. Annual maintenance costs, excluding staff salaries, are estimated to be about $US 100,000. Line rentals are not included in these figures.

In addition to the communications equipment and the computers, certain local utility requirements such as electric power, building maintenance, personnel offices and an air-conditioned computer laboratory would have to be provided. Costs of these services have not been estimated.

Besides the computer hardware, adequate standard software should be available. The standard software provided by the manufacturers of modern, large or medium size computers would generally be sufficient. Special programs would of course have to be provided for the main tasks of analysis. Proven programs
could in some cases be transferred from existing seismological data centres. The international data centres of the co-operative system should all use the same software in order to ensure identical initial processing of the global seismic data. The cost of developing the necessary software for the global co-operative system has not been considered in detail. However, similar efforts in the past indicate that a group of 10-15 programmers could complete this task in about a year.

The staff of an international data centre may consist of 10-12 scientists and technicians. During installation additional personnel would be needed.

The ad hoc group has not addressed the question of how the establishment and operation of the international centres would be financed by the participating States.

The estimated cost and manpower requirements of the various options presented in this chapter are summarized in table 8.2.
<table>
<thead>
<tr>
<th>Type of Station</th>
<th>Single Station (minimum variant)</th>
<th>Single Station (optimal variant)</th>
<th>Array Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification of Instruments</td>
<td>(70-100)K (SP)* (1-5)K (LP)*</td>
<td>(150-200)K (SP) (10-50)K (LP)</td>
<td>(150-200)K (SP) (10-50)K (LP) (for single instruments)</td>
</tr>
<tr>
<td>Recording Method</td>
<td>Photographic</td>
<td>Digital magnetic recording</td>
<td>Digital magnetic recording</td>
</tr>
<tr>
<td>Location of Seismometers</td>
<td>In the station basement</td>
<td>In boreholes, shafts, galleries</td>
<td>In boreholes</td>
</tr>
<tr>
<td>Methods of Detection and Measurement of Signal Parameters</td>
<td>Visual processing of seismograms</td>
<td>Automatic on-line computer processing and visual control</td>
<td>Automatic on-line computer processing and visual control</td>
</tr>
<tr>
<td>Type of First Level Data</td>
<td>See Tables 3.1 and 3.2</td>
<td>See Tables 3.1 and 3.2</td>
<td>See Tables 3.1 and 3.2</td>
</tr>
<tr>
<td>Type of Second Level Data</td>
<td>Photocopies of sections of seismograms containing an interesting signal</td>
<td>Photocopies or digital waveforms containing sections of the interesting signal</td>
<td>Photocopies or digital waveforms of the maximum beam</td>
</tr>
<tr>
<td>Method of transmitting First-Level Data to the Centers</td>
<td>WMO channels (telephone, telex as backup)</td>
<td>WMO channels (telephone, telex as backup)</td>
<td>WMO channels (telephone, telex as backup)</td>
</tr>
<tr>
<td>Method of transmitting Second-Level Data to the Centers</td>
<td>Air mail, photo-telegraphic WMO channels</td>
<td>Air mail, photo-telegraphic WMO channels</td>
<td>Air mail, photo-telegraphic, WMO-channels</td>
</tr>
</tbody>
</table>

*These requirements are relaxed for coastal and island stations where high noise levels will not permit such magnifications

Table 8.1

Equipment of Stations in the Global Network
<table>
<thead>
<tr>
<th></th>
<th>Equipment</th>
<th>Installation</th>
<th>Maintenance (per year)</th>
<th>Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Requirements for one standard station (minimum variant)</td>
<td>40 000</td>
<td>50 000</td>
<td>3 000</td>
<td>2-3</td>
</tr>
<tr>
<td>b) Additional requirements for desirable modifications of a standard station</td>
<td>40 000</td>
<td>1 000</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>c) Requirements for digital broad-band station (optimum variant)</td>
<td>200 000</td>
<td>100 000</td>
<td>20 000</td>
<td>3-4</td>
</tr>
<tr>
<td>d) Requirements for telecommunication for each station (1st and 2nd level)</td>
<td>10 000</td>
<td>1 000</td>
<td>5 000</td>
<td>no extra manpower</td>
</tr>
<tr>
<td>e) Requirements for a data center</td>
<td>500 000</td>
<td>200 000</td>
<td>100 000 excluding communication cost</td>
<td>10-12</td>
</tr>
</tbody>
</table>

Table 8.2
Approximate costs in US-dollars and manpower required for various components within the specified network.
Figure 8.1 Schematic view of a digital broad-band station.
Figure 8.2 Schematic view of a possible computer system at an international data center.
CHAPTER 9

PROPOSAL FOR AN EXPERIMENTAL EXERCISE

Summary

The international co-operative measures described in this document contain a number of elements that are new and unproven relative to past and current seismological practice. The Ad Hoc group therefore sees a need for an experimental exercise in order to:

- test the over-all functioning of the proposed system,
- determine experimentally the operating efficiency and any possible deficiencies of the specified system, including its capabilities in the southern hemisphere,
- test the telecommunications and data exchange procedures in a practical situation,
- obtain practical experience and thereby shorten the lead time necessary for the implementation of a procedure for international exchange of seismic data should this later be decided.

The experimental exercise would address the main elements of the international co-operative measures described in this document. A time period of at least six months would be required for the planning and co-ordination of such an exercise. An additional period of approximately one year would be required for the execution and evaluation of the experimental exercise.

Introduction

To establish international co-operative measures to detect and identify seismic events as proposed in this report will be an ambitious undertaking. The requirements with respect to data volume, speed of data exchange and quality of station operation significantly exceed those customary to existing seismological networks. The variety of stations with different instrumentation, routines and data formats add further difficulties that must be overcome. Finally, and most important, the goodwill of participating States to provide the necessary facilities and co-operate in the data exchange on the proposed scale will be essential for the success of a global seismological system.

The measures proposed in the preceding chapters by the Ad Hoc group are considered realistic and feasible within the current state of the art in seismology. However, while some elements of the proposed system are well known and thoroughly tested, others are new and have been investigated only theoretically. Likewise, the estimated capability of the proposed system to detect and locate seismic events and to obtain identification parameters can be verified only by experimental tests.
The Ad Hoc group therefore sees a need to conduct an experimental exercise relevant to the proposed system. The remainder of this chapter explains in more detail how the group has come to this conclusion, and also outlines such an experimental exercise.

9a. Proven and unproven elements of the co-operative system

The main operational elements of the proposed international co-operative measures to detect and to identify seismic events are as follows:

(i) to operate seismographs at more than 50 stations, located world-wide,
(ii) to extract basic signal parameters (at Level 1) at each station,
(iii) to transmit these data within certain time-limits to international data centres,
(iv) to process the collected data, locate seismic events and to associate identification parameters with the located events,
(v) to distribute information on location and identification parameters to each individual State,
(vi) upon request from individual States, to collect data from each station at Level 2 (i.e., complete seismic waveforms) for events of special interest, and to redistribute these data to the interested parties.

As to (i), station operation, there is expected to be little problem, as seismograph stations have been operated routinely for many years. However, the requirements set forth by the proposed system will be stricter in terms of operational efficiency that is now commonly the case. Moreover, it is desirable to install new or improved seismographs in selected locations, especially in South America and Africa.

As to (ii), parameter extraction, a common practice is again well established, as the necessary data to produce event locations are routinely extracted on a world-wide basis. However, the additional and very important task of measuring parameters relevant to event identification will be new to most of the stations of the global network.

As to (iii), Level 1 data exchange, the exchange of seismic data has long been a cornerstone of international seismological co-operation and research. However, current practice is most often based upon mail services, and rapid transmission such as telex is used by few countries. The rapid transmission of Level 1 data is an important component of the system as proposed by the Ad Hoc group. The utilization of the WMO/GTS for this purpose will be the most appropriate means. However, more experience in its practical use should be gained through an experimental exercise.

As to (iv), central processing, existing international data centres are routinely producing event parameters such as location, depth, origin time and magnitude, but the strict time requirements and complex data structures of the proposed system will necessitate increased processing capacity and the establishment of new operating routines. In particular, the compilation of
Identification parameters on a routine basis will represent a significant new development in the proposed system.

As to (v), dissemination of results, the utilization of the WMO/GTS is desirable for dissemination of information from the data centres. Special procedures must be established for this purpose.

As to (vi), Level 2 data exchange, there will be two main problems that need to be resolved: first, agreeing upon a workable format of the Level 2 data and, secondly, achieving a sufficiently fast exchange procedure. Telecopying, air mail and WMO/GTS have been proposed as transmission media in this report. However, only practical experience can show which one is the most appropriate.

9b. Outline of an experimental exercise

The purpose of an experimental exercise would be to test and evaluate the untested elements of the proposed system as discussed in 9a, and to identify any deficiencies in this system. Such an exercise would require the full co-operation of participating seismic stations, communication systems for data exchange at Levels 1 and 2 and data processing at participating international data centres.

The details of how to conduct an exercise, including the degree of comprehensiveness in the testing of the various system components, cannot be specified at this stage. However, the Ad Hoc group considers that priority should be given to detailed testing of the data exchange procedures, in particular the exchange of Level 1 data via the WMO/GTS.

The main benefit of an experimental exercise would be to provide a test of the over-all functioning of the data reporting and exchange procedures in the proposed global co-operative measures. One would also obtain a test of the network capability estimates of Chapter 5. In addition, the exercise would provide results of interest for the further improvement of identification parameters. For example, the obtained data will permit a further clarification of the reasons for differences in seismic magnitudes measured by different networks or by stations located on different continents.

In order to successfully conduct an experimental exercise, careful planning must be undertaken and detailed specifications must be made. Very likely it will be desirable to evaluate and test parts of the system in a preparatory phase, thus setting the stage for a gradual transition into the full-scale exercise. The planning and preparatory phase would probably require at least a 6-month period.

Not counting these preparations, the Ad Hoc group considers that the minimum useful time period for conducting the full-scale exercise would be 6 months, as this would be sufficient to test the data exchange and reporting procedures. However, a desirable time period would be 1 year, in order to collect adequate statistics on seismic events as well as on the seasonal variation of seismic noise from interesting regions of the globe. After completion of the exercise the experience gained would be extremely useful for the works of a permanent global system.

The material obtained in the course of an experimental exercise would be made available to all States Members of the CCD and to all other States participating in the exercise.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>The maximum deflection of a recorded seismic waveform.</td>
</tr>
<tr>
<td>Analog waveform</td>
<td>A seismic signal in a non-numeric representation (e.g., a visual waveform recorded on paper or an electronic representation by voltages, resistances, etc.).</td>
</tr>
<tr>
<td>ARPANET</td>
<td>A computer communication network established by the Advanced Research Projects Agency (ARPA), USA; used inter alia for transmission of seismic data. See chapter 6a.</td>
</tr>
<tr>
<td>Array</td>
<td>An ordered arrangement of seismometers, the data from which are fed into a central receiver. The number of seismometers in an array may range from three to several hundred and the array may be deployed over an area extending from a few up to more than a hundred km in diameter.</td>
</tr>
<tr>
<td>Arrival</td>
<td>The appearance of a seismic signal on a seismic record.</td>
</tr>
<tr>
<td>Arrival time</td>
<td>The time at which a seismic signal appears at a given site.</td>
</tr>
<tr>
<td>Azimuth</td>
<td>The direction from an event epicentre to a given seismograph station: measured clockwise as the angle between true north and a great circle connecting the epicentre and station location.</td>
</tr>
<tr>
<td>BDAC</td>
<td>Blacknest Data Analysis Centre (United Kingdom): See chapter 7a.</td>
</tr>
<tr>
<td>Body wave</td>
<td>A seismic wave (longitudinal or shear) that travels through the interior of the earth along various paths.</td>
</tr>
<tr>
<td>Body wave magnitude</td>
<td>see m&lt;sub&gt;b&lt;/sub&gt;.</td>
</tr>
<tr>
<td>Broad-band instruments</td>
<td>Seismographs that record a wide range of signal frequencies, thus encompassing the short period and long period bands.</td>
</tr>
<tr>
<td>CCITT</td>
<td>Consultative Committee for International Telephone and Telegraph Services.</td>
</tr>
<tr>
<td>CERESIS</td>
<td>Regional seismological centre for South America: see appendix IV.</td>
</tr>
<tr>
<td>Complexity</td>
<td>An identification parameter of seismic events describing the form of the envelope of the recorded P-wave at a given station (see chapter 3b).</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Degree</td>
<td>Besides its standard meaning, also a measure of distance between an event epicentre and a station along a great circle path. (one degree is approximately 111 km).</td>
</tr>
<tr>
<td>Depth phases</td>
<td>Seismic waves that have been reflected from the earth's surface above the event hypocentre (e.g., pP and sP).</td>
</tr>
<tr>
<td>Digital</td>
<td>A seismic signal represented as a sequence of numbers corresponding to equidistant time intervals (e.g., 0.05 s or 1 s).</td>
</tr>
<tr>
<td>Elastic wave</td>
<td>A wave that propagates by some kind of elastic deformation, i.e., a deformation that disappears when the forces are removed.</td>
</tr>
<tr>
<td>EMSC</td>
<td>European-Mediterranean Seismological Centre (France): See chapter 7a.</td>
</tr>
<tr>
<td>Epicentre</td>
<td>The point on the earth's surface which is directly above the event hypocentre.</td>
</tr>
<tr>
<td>Filtering</td>
<td>The process of operating on any signal to select particular bands of frequencies of vibration and suppress others.</td>
</tr>
<tr>
<td>First motion</td>
<td>An identification parameter describing the direction of P-wave onset at a given station (either an upward push or a downward pull) (See chapter 3b).</td>
</tr>
<tr>
<td>FM</td>
<td>Frequency modulation; a technique for data transmission.</td>
</tr>
<tr>
<td>Focal depth</td>
<td>The depth at which the source of a seismic event is located.</td>
</tr>
<tr>
<td>Focus, focal point</td>
<td>The point within the earth from which the first energy of a seismic event originates.</td>
</tr>
<tr>
<td>Great circle</td>
<td>A circle on the surface of the earth formed in such a way that the plane of the circle passes through the centre of the earth.</td>
</tr>
<tr>
<td>GTS</td>
<td>Global Telecommunications System of the World Meteorological Organization (chapter 6a).</td>
</tr>
<tr>
<td>Hypocentre</td>
<td>The location of the focus of a seismic event.</td>
</tr>
<tr>
<td>ISC</td>
<td>International Seismological Centre (United Kingdom); see chapter 7a.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ISM</td>
<td>International Seismic Month; an experiment in seismic data collation and analysis co-ordinated by the Lincoln Laboratories, USA; see chapter 2.</td>
</tr>
<tr>
<td>kt</td>
<td>kiloton, used as a unit for measuring explosive yields (see appendix I).</td>
</tr>
<tr>
<td>Longitudinal wave</td>
<td>An elastic wave characterized by compressional and rarefractional particle motions.</td>
</tr>
<tr>
<td>Long period waves</td>
<td>Seismic waves of periods of more than 10 seconds.</td>
</tr>
<tr>
<td>Love wave</td>
<td>A surface wave having a horizontal motion transverse to the direction of propagation.</td>
</tr>
<tr>
<td>LP</td>
<td>See Long period.</td>
</tr>
<tr>
<td>LPZ</td>
<td>Used to denote the vertical component of a long period seismograph.</td>
</tr>
<tr>
<td>LQ</td>
<td>Standard abbreviation for 'Love wave'.</td>
</tr>
<tr>
<td>LR</td>
<td>Standard abbreviation for 'Rayleigh wave'.</td>
</tr>
<tr>
<td>Magnitude</td>
<td>A measure of the size of a seismic event, as determined by seismographic observations (see ( m_b ), ( M_s )).</td>
</tr>
<tr>
<td>( m_b )</td>
<td>Magnitude calculated from the amplitude and period of a recorded P-wave (also called body-wave magnitude).</td>
</tr>
<tr>
<td>( M_s )</td>
<td>Magnitude calculated from the amplitude and period of a recorded Rayleigh wave (also called surface-wave magnitude).</td>
</tr>
<tr>
<td>( M_s : m_b )</td>
<td>An identification parameter of seismic events based upon the relative difference in excitation of surface waves and body waves. For the same value of ( m_b ), earthquakes usually have higher ( M_s ) than explosions (See chapter 3b).</td>
</tr>
<tr>
<td>NEIS</td>
<td>National Earthquake Information Service (United States of America); see chapter 7a.</td>
</tr>
<tr>
<td>Noise</td>
<td>Slight, continually present vibrations of the earth's surface arising from either natural or man-made causes (e.g., wind, sea waves, traffic, industrial activity).</td>
</tr>
<tr>
<td>Off-line computer</td>
<td>A computer used to process data previously recorded on magnetic tape. The delay between recording and processing may range up to many years.</td>
</tr>
<tr>
<td>On-line computer</td>
<td>A computer used to process incoming data with little or no time delay.</td>
</tr>
</tbody>
</table>

-110-
P or P-wave  
(primary wave)  - A longitudinal seismic wave, i.e., consisting of push-pull motions of the elastic material. The P-wave propagates through the interior of the earth and is the fastest propagating seismic wave.

pP  - A P-wave that has been reflected at the earth's surface above the event hypocentre. The time delay between a recorded P and pP is proportional to the focal depth of the event.

PDE  - Preliminary Determination of Epicentres, a service provided by the NEIS (chapter 7a).

Parameter  - A quantity, the value of which describes a certain physical, mathematical or statistical property.

Period  
(or signal period)  - The time interval corresponding to one cycle of a vibration on a seismogram.

Phase  - The arrival on a seismic record of a different type or class of seismic wave. (P, PP, PkP, PcP, etc.).

Polarized wave  - A wave having particle vibrations in a definite pattern.

Rayleigh wave  - A surface wave characterized by an elliptical motion in the vertical plane.

RHEL  - Rutherford High Energy Laboratory (appendix IV).

S or S-wave  
(secondary wave)  - A seismic wave of the shear type which propagates through the interior of the earth.

SDAC  - Seismic Data Analysis Center (USA): see chapter 7a.

Seismic waves  
(signals)  - Elastic waves generated by a seismic event (e.g., P, S, LR, LQ).

Seismogram  - A visual seismic record containing waveforms covering a certain time interval (e.g., 24 hours).

Seismograph  - A seismic recording system which includes a seismometer, a recorder and timing systems.

-111-
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismometer</td>
<td>An instrument designed to detect the earth motions caused by seismic waves. Most observatories have triaxial seismometers, which detect ground motion separately in the vertical and two horizontal (North-South, East-West) directions. The natural period of vibration of seismometers is usually designed to be either about 1 second (short period) or about 20 seconds (long period).</td>
</tr>
<tr>
<td>Shear wave</td>
<td>An elastic wave characterized by transverse particle motions; polarized either in the vertical or horizontal plane.</td>
</tr>
<tr>
<td>Short period waves</td>
<td>Conventionally used to describe seismic waves of periods around 1 second.</td>
</tr>
<tr>
<td>SIPRI</td>
<td>Stockholm International Peace Research Institute (Sweden).</td>
</tr>
<tr>
<td>S/N (Signal-to-noise ratio)</td>
<td>The comparison between the amplitude of a signal from a seismic event (as recorded at a given station) and the amplitude of the seismic noise at the station.</td>
</tr>
<tr>
<td>SP</td>
<td>See Short period.</td>
</tr>
<tr>
<td>Spectrum, spectral content</td>
<td>The energy distribution of vibrations of seismic waves at different frequencies within a certain frequency band. Of particular interest for identification purposes are the short period spectral band (vibrations around 1 second per cycle) and the long period spectral band (vibrations around 20 seconds per cycle).</td>
</tr>
<tr>
<td>sP</td>
<td>Analagous to pP: an S-wave reflected at the surface above the event hypocentre and converted to a P-wave.</td>
</tr>
<tr>
<td>SPZ</td>
<td>Used to denote the vertical component of a short period seismograph.</td>
</tr>
<tr>
<td>Surface wave</td>
<td>A seismic wave that propagates along paths near to and parallel with the surface of the earth (see also Love and Rayleigh waves).</td>
</tr>
<tr>
<td>Surface wave magnitude</td>
<td>See $M_s$.</td>
</tr>
</tbody>
</table>

-112-
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teleseismic zone</td>
<td>The distance range of about 25 to 100 degrees from a seismograph station</td>
</tr>
<tr>
<td>(third zone)</td>
<td>(see chapter 3a).</td>
</tr>
<tr>
<td>Travel time</td>
<td>The time it takes for a given seismic wave to propagate over a certain</td>
</tr>
<tr>
<td></td>
<td>distance.</td>
</tr>
<tr>
<td>Widesband</td>
<td>See broad-band.</td>
</tr>
<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
</tr>
<tr>
<td>WWSSN</td>
<td>World-Wide Standardized Seismograph Network (see chapter 2).</td>
</tr>
</tbody>
</table>
# List of Abbreviations of Seismograph Stations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAE</td>
<td>Addis Ababa, Ethiopia</td>
</tr>
<tr>
<td>AFI</td>
<td>Afiamalu, Western Samoa, New Zealand</td>
</tr>
<tr>
<td>ALE</td>
<td>Alert, Northwest Territory, Canada</td>
</tr>
<tr>
<td>ALPA</td>
<td>Alaskan Long Period Array, Alaska, United States</td>
</tr>
<tr>
<td>ANMO</td>
<td>New Mexico Observatory, United States</td>
</tr>
<tr>
<td>ANTO</td>
<td>Ankara, Turkey Observatory, Turkey</td>
</tr>
<tr>
<td>AQU</td>
<td>Aquila, Italy</td>
</tr>
<tr>
<td>ARE</td>
<td>Arequipa, Peru</td>
</tr>
<tr>
<td>ASP</td>
<td>Alice Springs, Northern Territory, Australia</td>
</tr>
<tr>
<td>BDF</td>
<td>Brasilia Array, Brazil</td>
</tr>
<tr>
<td>BNG</td>
<td>Bangui, Central African Empire</td>
</tr>
<tr>
<td>BOCO</td>
<td>Bogota, Colombia Observatory, Colombia</td>
</tr>
<tr>
<td>BOD</td>
<td>Bodaybo, Central Siberia, Soviet Union</td>
</tr>
<tr>
<td>BUD</td>
<td>Budapest, Hungary</td>
</tr>
<tr>
<td>BUL</td>
<td>Bulawayo, Rhodesia</td>
</tr>
<tr>
<td>CHTO</td>
<td>Chiang Mai Observatory, Thailand</td>
</tr>
<tr>
<td>COL</td>
<td>College outpost, Alaska, United States</td>
</tr>
<tr>
<td>COM</td>
<td>Comitan, Mexico</td>
</tr>
<tr>
<td>CTA</td>
<td>Charters Towers, Queensland, Australia</td>
</tr>
<tr>
<td>DAG</td>
<td>Danmarkshavn, Greenland, Denmark</td>
</tr>
<tr>
<td>DBN</td>
<td>De Bilt, Netherlands</td>
</tr>
<tr>
<td>DOU</td>
<td>Dourbes, Belgium</td>
</tr>
<tr>
<td>DUG</td>
<td>Dugway, Utah, United States</td>
</tr>
<tr>
<td>EIL</td>
<td>Eilat, Israel</td>
</tr>
<tr>
<td>EKA</td>
<td>Eskdalemuir Array, Scotland, United Kingdom</td>
</tr>
<tr>
<td>ELT</td>
<td>Eltsovka, Western Siberia, Soviet Union</td>
</tr>
<tr>
<td>FFC</td>
<td>Flin Flon, Manitoba, Canada</td>
</tr>
<tr>
<td>FVM</td>
<td>French Village, Missouri, United States</td>
</tr>
<tr>
<td>GACO</td>
<td>Glen Almond, Quebec, Canada</td>
</tr>
<tr>
<td>GBA</td>
<td>Gauribidanur Array, India</td>
</tr>
<tr>
<td>GDH</td>
<td>Godhavn, Greenland, Denmark</td>
</tr>
<tr>
<td>GRF</td>
<td>Grafenberg Array, Federal Republic of Germany</td>
</tr>
<tr>
<td>GUMO</td>
<td>Guam Observatory, Guam, (United States)</td>
</tr>
<tr>
<td>Code</td>
<td>Location</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
</tr>
<tr>
<td>HFS</td>
<td>Hagfors Observatory, Sweden</td>
</tr>
<tr>
<td>HLW</td>
<td>Helwan, Egypt</td>
</tr>
<tr>
<td>HYB</td>
<td>Hyderabad, India</td>
</tr>
<tr>
<td>IFR</td>
<td>Ifrane, Morocco</td>
</tr>
<tr>
<td>ILPA</td>
<td>Iranian Long Period Array, Iran</td>
</tr>
<tr>
<td>ISK</td>
<td>Istanbul-Kandilli, Turkey</td>
</tr>
<tr>
<td>JYSA</td>
<td>Jyväskylä Seismic Array, Finland</td>
</tr>
<tr>
<td>KBL</td>
<td>Kabul, Afghanistan</td>
</tr>
<tr>
<td>KDZ</td>
<td>Kurdzhali, Bulgaria</td>
</tr>
<tr>
<td>KEV</td>
<td>Kevo, Finland</td>
</tr>
<tr>
<td>KHC</td>
<td>Kašperské Hory, Czechoslovakia</td>
</tr>
<tr>
<td>KIC</td>
<td>Kosan Boka, Ivory Coast</td>
</tr>
<tr>
<td>KIP</td>
<td>Kipapa Oahu, Hawaii, United States</td>
</tr>
<tr>
<td>KJF</td>
<td>Kajaani, Finland</td>
</tr>
<tr>
<td>KOD</td>
<td>Kodaikanal, India</td>
</tr>
<tr>
<td>KRA</td>
<td>Cracow, Poland</td>
</tr>
<tr>
<td>KSRS</td>
<td>Korean Seismic Research Station, South Korea</td>
</tr>
<tr>
<td>KTG</td>
<td>Kap Tobin, Greenland, Denmark</td>
</tr>
<tr>
<td>LASA</td>
<td>Large Aperture Seismic Array, Montana, United States</td>
</tr>
<tr>
<td>LEM</td>
<td>Lembang, Java, Indonesia</td>
</tr>
<tr>
<td>LJU</td>
<td>Ljubljana, Yugoslavia</td>
</tr>
<tr>
<td>LOR</td>
<td>Lormes, France</td>
</tr>
<tr>
<td>LPA</td>
<td>La Plata, Argentina</td>
</tr>
<tr>
<td>LPZ</td>
<td>La Paz, Bolivia</td>
</tr>
<tr>
<td>MAIO</td>
<td>Mashad, Iran Observatory, Iran</td>
</tr>
<tr>
<td>MAT</td>
<td>Matsushiro, Japan</td>
</tr>
<tr>
<td>MAW</td>
<td>Mawson, Antarctica (United States)</td>
</tr>
<tr>
<td>MBC</td>
<td>Mould Bay, Northwest Territory, Canada</td>
</tr>
<tr>
<td>MDZ</td>
<td>Mendoza, Argentina</td>
</tr>
<tr>
<td>MLR</td>
<td>Cheia, Romania</td>
</tr>
<tr>
<td>MOX</td>
<td>Moxa, German Democratic Republic</td>
</tr>
<tr>
<td>NDI</td>
<td>New Delhi, India</td>
</tr>
<tr>
<td>NORSAR</td>
<td>Norwegian Seismic Array, Norway</td>
</tr>
<tr>
<td>NIE</td>
<td>Niedzica, Poland</td>
</tr>
<tr>
<td>NIKO</td>
<td>Nairobi, Kenya Observatory, Kenya</td>
</tr>
<tr>
<td>NWAO</td>
<td>Narrogin Observatory, Australia</td>
</tr>
<tr>
<td>Code</td>
<td>Location Description</td>
</tr>
<tr>
<td>------</td>
<td>----------------------</td>
</tr>
<tr>
<td>OBN</td>
<td>Obninsk, Central Russia, Soviet Union</td>
</tr>
<tr>
<td>OGD</td>
<td>Ogdensburg, New Jersey, United States</td>
</tr>
<tr>
<td>PEL</td>
<td>Peldehue, Chile</td>
</tr>
<tr>
<td>PNS</td>
<td>Penas, Bolivia</td>
</tr>
<tr>
<td>QUE</td>
<td>Quetta, Pakistan</td>
</tr>
<tr>
<td>RBA</td>
<td>Rabat, Morocco</td>
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<tr>
<td>SAL</td>
<td>Salo', Italy</td>
</tr>
<tr>
<td>SBA</td>
<td>Scott Base, Antarctica (New Zealand)</td>
</tr>
<tr>
<td>SHI</td>
<td>Shiraz, Iran</td>
</tr>
<tr>
<td>SHIO</td>
<td>Shillong Observatory, India</td>
</tr>
<tr>
<td>SHL</td>
<td>Shillong, India</td>
</tr>
<tr>
<td>SJG</td>
<td>San Juan, Puerto Rico</td>
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<td>SMA</td>
<td>Sanae, Antarctica (South Africa)</td>
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<tr>
<td>SPA</td>
<td>South Pole, Antarctica (United States)</td>
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<td>TAM</td>
<td>Tamanrasset, Algeria</td>
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<td>TLL</td>
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<td>Mexico University, Mexico</td>
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<td>Valandovo, Yugoslavia</td>
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<td>WEL</td>
<td>Wellington, New Zealand</td>
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<td>WES</td>
<td>Weston, Massachusetts, United States</td>
</tr>
<tr>
<td>WIN</td>
<td>Windhoek, Southwest Africa (Namibia)</td>
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<tr>
<td>WRA</td>
<td>Warramunga Array, Northern Territory, Australia</td>
</tr>
<tr>
<td>WTS</td>
<td>Winterswijk, The Netherlands</td>
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<tr>
<td>YAK</td>
<td>Yakutsk, Eastern Siberia, Soviet Union</td>
</tr>
<tr>
<td>YKA</td>
<td>Yellowknife Array, Northwest Territory, Canada</td>
</tr>
</tbody>
</table>
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APPENDIX I

Problems with the estimation of yields of contained underground nuclear explosions

Introduction

Yields are usually given in kilotons (kt), where 1 kt is defined as $4.2 \times 10^{12}$ J which is roughly the energy released by exploding 1,000 tons of trinitrotoluene (TNT).

Most of the energy radiated by an underground nuclear explosion is deposited as thermal energy in the immediate vicinity of the explosion, and only a small fraction is radiated as seismic waves. The fraction of the seismic energy radiated to teleseismic distances has in SIPRI (1968) been estimated to range from 0.1 per cent (dry alluvium) to 1 per cent (granite).

The strength of the seismic signals depends strongly on the medium in which the explosion is carried out. Explosions in hard rocks, like granite, give considerably stronger signals than do explosions in unconsolidated media, like clay and alluvium. The relative coupling between granite, tuff and dry alluvium has in SIPRI (1968) been estimated to 1, 0.5 and 0.1, respectively. The signals recorded at a seismic station depend not only on the explosion yield and the shot medium, but also on the wave transmission properties of the earth. These transmission properties vary considerably from one region to the other. The strong dependence of seismic signals on both the shot medium and the signal transmission properties from the test site to the seismological stations makes it important to proceed with great care in the estimation of explosion yields, and it is therefore important to use seismic data from a fixed station network for such estimates. Because of the uncertainty of inter alia the transmission path effects, it is difficult to calculate explosion yields directly from seismic signals, and yields have to be estimated in relation to a nearby calibration explosion the yield of which is known from radio-chemical or close-in shock wave measurements. The yield of an explosion estimated from seismic signals is usually given as the equivalent yield of an explosion in standard hard rock like tuff or granite. This means that the observed seismic signals correspond to those expected from a fully contained explosion in hard rock in the actual test area of equivalent yield. If detailed information about the testing conditions, such as the explosion medium, emplacement depth and depth of static water table, is available, closer yield estimates are possible. For a high yield explosion the equivalent yield will be rather close to the real yield, as such an explosion can be contained only at depths where hard-rock conditions usually exist. For a low-yield explosion, which could be contained at shallow depth in unconsolidated alluvial material, the real yield can be several times higher than the estimated equivalent hard-rock yield. The variability in coupling conditions within such an unconsolidated material could be expected to be larger than in hard rock, which fact will increase the uncertainties in the yield estimates of explosions in such media.
Seismic magnitudes for yield estimation

The concept of seismic magnitude, m, originally introduced to bring uniformity to earthquake statistics, has also been used to estimate the yields of nuclear explosions. General formulae, such as \( m = a \log_{10} Y + b \), have been widely discussed. Y denotes the yield and a and b are constants. Theoretical source models for explosions predict the following: (i) for long-period surface waves, with period around 20 s, a linear relation with a slope close to 1 between the logarithm of the explosion yield and the logarithm of the signal amplitude (or magnitude), (ii) for short-period signals at 1 Hz and above, the slope is less than one and decreases with increasing yield, particularly at high yields (Haskell, 1967; Mueller and Murphy, 1971).

The wavelengths of the long-period Rayleigh waves are considerably greater than those of the P waves, and are thus less influenced by small-scale heterogeneities at the test site and along the wave path. To take into account the large-scale regional variations which do exist also for these waves, a new path-corrected surface-wave magnitude scale has been introduced (Marshall and Basham, 1972). This scale claims surface-wave magnitude estimates which are independent of where the explosions and the stations are located. For low-yield nuclear explosions the recorded surface Rayleigh waves have, however, relatively short periods of 10-15 seconds which may be subject to significant regional variance and the relationships obtained by Marshall and Basham (1972) might therefore not be applicable. In this case the magnitude \( M_s \) significantly depends on the conditions at the test site, along the surface wave path and at the recording site. Special care must therefore be taken using this type of data for yield estimation (Pasechnik, 1970). In cases of low-yield explosions Rayleigh waves are also not always recorded at large distances and P-waves are therefore more useful in the yield estimation of such explosions at teleseismic distances. Attempts have also been made (Bisztricsany, 1977) to utilize the duration of surface waves for estimating explosion yields.

Calibration data

We noted earlier in this appendix that calibration explosions with known yields are essential for accurate yield estimates. Such calibrations explosions are today generally available only for a few places, almost all of which are located in the United States. Yields have been released for a number of underground nuclear explosions at the Nevada Test Site, NTS (Zander and Araskog, 1973; Springer and Kinnaman, 1971, 1975). Only about 30 of these explosions have however been recorded by a significant number of stations, and thus can be used for calibrating Nevada type geology. The United States has also officially announced the yields of four Peaceful Nuclear Explosions (PNEs) in different parts of the western United States and of one nuclear test detection explosion at the test site in the Aleutian Islands which can be used for calibrating those areas.

The USSR has not officially announced any yield of nuclear explosions at its main test sites. However, yields, but not places and times, have been reported for several peaceful nuclear explosions in the USSR. The limited amount of generally available calibration data may introduce systematic uncertainty in the yield estimates for explosions in the USSR.
Published magnitude-yield relations

Most of the published relations between yield and short-period amplitude or magnitude are based on United States explosions at the Nevada Test Site (Ericsson, 1971a; Basham and Horner, 1973; Springer and Hannon, 1973; Dahlman and Israelson, 1977).

A few attempts have also been made to estimate relations between explosion yield and short-period magnitude or signal amplitude for explosions in the USSR although less announced yield data are generally available (Ericsson, 1971a; Basham and Horner, 1973; Dahlman and Israelson, 1977).

Relations between explosion yields for NTS explosions and observed surface-wave amplitudes or magnitudes have been published by Springer and Hannon (1973) and Ericsson (1971b).

Marshall et al. (1971) estimated a magnitude-yield relation based on long-period data obtained at a variety of stations from 31 explosions at various places in the United States, the USSR and Africa. For some of the explosions the yields were officially announced, whereas for others they are obtained from non-official sources, such as newspapers. The magnitudes are calculated using a magnitude formula that includes path correction. The relation is claimed to be valid for explosions in consolidated rocks at any site.

Accuracy

When discussing the accuracy of yield estimates, we must consider both the accuracy in estimating the equivalent yields for explosions in tuff or hard rock and the accuracy in converting such equivalent-yield estimates into real explosion yields taking the actual coupling conditions into account. The estimates of equivalent tuff yields for NTS explosions are probably the most accurate ones that can be made with calibration data available today. Ericsson (1971b) and Basham and Horner (1973) suggested that the average error of such estimates is of the order of 10-50 per cent.

Studies published by Dahlman and Israelson (1977) suggest that for NTS explosions in tuff and rhyolite 90 per cent of the studied explosions had an error in the estimated yield that was less than 50 per cent of the announced yield.

Estimation of network capabilities in terms of explosion yield

Various published methods of estimating explosion yields from reported seismic data have been discussed above as well as the accuracy that may be achieved in such estimates. When discussing an estimated capability of an international seismic data exchange system, e.g., to detect, locate and identify events, it might for certain purposes be more convenient to express the capability in equivalent hard rock yield rather than in magnitude.

To obtain the estimated capability of a certain network in terms of equivalent hard rock yield (Y) rather than magnitude, formulae of the following form may be used for short period data:

\[ m_b = a \log_{10} Y + b \]  
(Y measured in kt)
The coefficient $a$ depends somewhat on the explosion medium, recording distance and on the size of the explosion. The value of $a$ is generally considered to be in the range 0.8-1.0 for data obtained at teleseismic distances from explosions in the yield range of 1-100 kt. The $b$-value is more strongly dependent on the explosion medium, on the geographical location of explosion and recording stations and on the type of instrumentation used for recording. The coefficient $b$ characterizes the magnitude of an explosion of a 1 kt yield. It should be noted that the relationship between $m_b$ and $Y$ in the above-mentioned form for explosions in Nevada tuff was suggested by Riznichenko (1960), who found $a=0.5\pm 0.06$, $b=4.6\pm 0.1$. For explosions in hard rock, $b$-values in the range 3.8-4.5 have been proposed by various authors. For long-period surface wave data a similar formula

$$M_s = A \log_{10} Y + B$$

can be used. $A$ is generally supposed to be around 1 and $B$ to be of the order of 2.

It must be observed that any such magnitude-yield relation has to be applied with great care, taking into account the actual station distribution and the receiving conditions of the individual station. If the formulae are applied uncritically for the yield estimation of a specific event, a considerable uncertainty may be introduced.
APPENDIX II

Appendix to chapter 2: a review of earlier relevant studies

The purpose of this appendix is to discuss technical aspects of the developments described in chapter 2 d. In particular, tables are presented that summarize the results of some earlier theoretical and experimental network capability studies.

Network capability studies

The 1968 SIPRI expert conference produced a comprehensive report discussing the capabilities of existing seismic networks, and also made proposals for how these capabilities could be improved. Taking into account the possible variability in the yield-magnitude relationship such as could be inferred from the data available at the time, the group concluded that with the installation of improved networks, yields down to 10 kt in hard rock, corresponding to $m_b$ around 5.0 might be identified from anywhere in the northern hemisphere with a high degree of probability. The limiting factor was the detection capability of surface (Rayleigh) waves needed to apply the $M_S - m_b$ discriminant. However, evidence was presented that the separation of earthquakes from explosions by this criterion extends at least to $m_b = 4$ (SIPRI, 1968; Pasechnik, 1970; Marshall, 1970). According to Pasechnik (1970) and SIPRI (1968), the tendency of the $M_S - m_b$ trend lines of explosions and earthquakes to diverge at low magnitudes is observed.

Some of the results of the SIPRI conference are summarized in tables A2-1 to A2-3. These tables further present the main results from the study by Basham and Whitham (1971), in the context of the United Nations assessment of world-wide data availability discussed in chapter 2d. Moreover, theoretical location capabilities provided by Evernden (1971) for selected global networks are included in table A2-3 for comparison. Table A2-4 summarizes results from analyses of P and Rayleigh wave detection capabilities based on data from the International Seismic Month (ISM).

The capabilities of the seismograph network established in the socialist countries of Europe have been studied in particular by USSR seismologists. Their estimate is that this network is capable of detecting underground nuclear explosions in the northern hemisphere down to a yield of about 5 kt (fully coupled to hard rock). This yield corresponds to $m_b = 5.0$ (Pasechnik, 1970). The accuracy of epicenter determination is a few tens of km (Pasechnik et al., 1960).

To demonstrate what a typical national verification procedure for earthquake screening could achieve in the context of a test ban, Basham and Anglin (1973) applied successive procedures to identify ISM earthquakes based on Canadian observations alone. The criteria were:

(i) Oceanic epicenters

(ii) Focal depth greater than 10 km

(iii) $M_S > 1.5 \times m_b - 3.4$
(iv) The value of a P-wave discriminant based on a combination of complexity and spectral content.

These criteria were applied to 291 ISM events from Eurasia with $m_b \geq 4$. The annual number of unidentified events from a typical area, the Sino-Soviet land mass, was estimated to increase from 13 for $m_b \geq 4.5$ to 328 for $m_b \geq 4$. The principal conclusions which could be drawn from the investigation were

(i) Despite being the most exclusive and thorough compilation of network data to date, the ISM data are incomplete for $m_b < 4.3$.

(ii) Basham and Anglin also concluded that discriminants based on teleseismic data are unlikely to be effective for all events of $m_b \geq 4.0$.

Current research efforts

Seismological research between 1963, the year of PTBT, and the 1968 SIPRI study led to the accumulation of substantial evidence for the effectiveness of the ratio of surface and body wave magnitudes ($M_s/m_b$) as an identifier of underground explosions. Though a theoretical basis for this discriminant exists, it has not yet been experimentally verified in a systematic way. The larger shear movements and relatively large volumes of source medium associated with earthquakes provide the basis for expecting larger excitation of shear and surface waves compared to underground explosions of the same P-wave energy.

Among the research results of later years, the most significant in the present context are briefly described in the following. Details of these and other developments may be found in the bibliography of this report.

(i) Improvements in location of seismic events

Various new methods have been developed for improved location of epicentre, notably The Joint Epicentral Determination (Douglas, 1967) and multi-array location techniques. Moreover, several studies (e.g., Herrin et al., 1968) have been performed to improve travel time-tables of seismic waves, in view of their crucial importance to event location. Kogan (1976) analysed statistically some 2000 P-wave travel times for which the epicentral co-ordinates and time at focus were precisely known. The epicentres were situated in North America, Asia and Europe. Focus corrections to P-wave travel times were established for epicentral areas according to the peculiarities of their seismological structure. The real travel times of P-waves in a range of epicentral distances from 30° to 104° proved to be two seconds less than those arrived at from the commonly used Jeffreys-Bullen tables. Time corrections were determined for the travel times of P-waves recorded in various tectonic areas of the earth. This has made possible a substantial improvement in the accuracy with which the location of epicentres of earth tremors from surface foci can be determined.

(ii) Magnitude studies

Several attempts have been made to identify the causes for the large observed station-to-station scatter in body wave as well as surface wave magnitudes. In this respect the formulation by Marshall and Basham (1972) of the period-dependent path corrections for different geographical regions and
source depths has provided an improved method for measuring $M_s$ and has focused attention on the need to extend similar investigations to other source-receiver paths. In the case of $m_b$ ray tracing and modelling techniques help to assess the contribution of multipathing as well as focusing and defocusing due to structural inhomogeneities with greater confidence. Pasechnik (1972) has shown that much of the magnitude scatter could be reduced at the expense of sensitivity by using instruments with uniform response to a wide band of ground motion periods and by installing them on unweathered rock substrata.

(iii) **Lowering of detection thresholds**

Increased signal strength relative to background noise can be obtained by the following methods:

- Judicious choice of sites based on evaluation of statistical properties of noise to ensure high signal strength and low ambient noise levels.

- Use of bore holes for installing seismic sensors with remote adjustments and calibration facilities to reduce the contribution from atmosphere-induced noise which decays rapidly with depth.

- Effective methods to extract signals from multichannel array data, such as linear or logarithmic summation with phase shift, prediction filtering, advanced methods of spectral estimation and successive subtraction of coherent noise by repeated application of the standard phase-summation procedure.

(iv) **Lowering of identification thresholds**

A principal objective has been to close the gap between the detection and identification thresholds of seismic events. The disadvantage of using surface waves for discrimination (such as in the $M_s$:$m_b$ criterion) is that they are more difficult to detect than P-waves. In consequence, attempts to develop P-wave discriminants are prominent. The full potential of these methods may be realized when it becomes possible to establish norms for regional effects on the recorded waveforms.

Deconvolution techniques are useful for resolving the surface reflected wave $pP$. When this wave can be identified, depth of focus can be reliably computed. Deconvolution is an example of the "inverse problem" of seismology - recovering the source from the seismogram. The direct or "forward" approach starts with a hypothetical source and attempts to reproduce an observed seismogram. This technique of seismogram modelling is also emerging as a useful tool for discriminating between the P-wave trains of explosions and earthquakes.

(v) **Theoretical studies**

The modelling techniques mentioned above combined with theoretical work on earthquake source mechanism has led to considerable improvements in understanding the dependence of P, LR and LQ waves and their relative excitation on rupture area, direction of slip and stress characteristics. A basis has been established for evaluating the partition of energy among the different modes of surface waves as a function of source depth and fault plane
orientation. Use is made of observations of motion in the immediate vicinity of underground nuclear explosion sources, and of numerical models for these sources and the earth structure surrounding them, to explain the nature of teleseismic signals in terms of explosion strength, depth and other parameters. Estimation of signal as well as magnitude from a network can now be made on maximum likelihood probabilistic basis. The use of combined criteria on large earthquake-explosion populations is aided by statistical techniques and decision theory. Ideas derived from statistical communication theory, multivariate analysis and pattern recognition have been adapted for event classification.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description of Network &amp; Data Base</th>
<th>Minimum No. of detections</th>
<th>Interval Probability</th>
<th>Range of Magnitude</th>
<th>Regions Covered</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>44 stations of WWSSN, selected on the basis of low noise &amp; geographical distribution</td>
<td>Asia (14)</td>
<td>90%</td>
<td>4.5 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 4.75</td>
<td>Most of N. &amp; S. America, Africa, Southeast Asia</td>
<td>Press &amp; Herrin SIPRI (1968)</td>
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<td></td>
<td></td>
<td>Europe (8)</td>
<td></td>
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<td>Africa (7)</td>
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<td></td>
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<td>Australia (1)</td>
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<td></td>
<td></td>
<td>South Pole (1)</td>
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<td></td>
<td></td>
<td>Greenland (1)</td>
<td></td>
<td>4.75 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 5.0</td>
<td>Australia</td>
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<td>N. America (7)</td>
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<td></td>
<td></td>
<td>S. America (5)</td>
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<td>2.</td>
<td>46 station SPZ network selected from UN returns of 1970.</td>
<td>CONVENTIONAL Asia (7)</td>
<td></td>
<td>4.0 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 4.2</td>
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<td>Basham &amp; Whitham (1971)</td>
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<td>New Zealand (2)</td>
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<td>N. America (7)</td>
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<td></td>
<td></td>
<td>Mexico (5)</td>
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<td>4.2 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 4.4</td>
<td>India, Southern Russia, Northern Africa, China, Northern part of S. America</td>
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<td>Africa (5)</td>
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<td>Antarctica (2)</td>
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<td>4.4 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 4.6</td>
<td>Australia, Southeast Asia, Central part of S. America &amp; Africa</td>
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<td>ARRAYS</td>
<td>GBA (India)</td>
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<td>4.6 ≤ m&lt;sub&gt;b&lt;/sub&gt; ≤ 4.8</td>
<td>Remaining parts of S. America &amp; Africa</td>
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<td>YKA (Canada)</td>
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<td>EKA (UK)</td>
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**TABLE A2-2**

Earlier Studies of the Detection Capability of Various Seismograph Networks for Long Period Rayleigh Waves – Model Studies

<table>
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<tr>
<th>Sr. No.</th>
<th>Description of Network</th>
<th>Distribution &amp; Data Base</th>
<th>Minimum No. of Detections</th>
<th>Interval Probability</th>
<th>Range of Magnitude</th>
<th>Regions Covered</th>
<th>Reference</th>
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<td>1.</td>
<td>44 stations of WWSSN</td>
<td>Asia (14)</td>
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<td></td>
<td>4.25 &lt; M_s &lt; 4.5</td>
<td>Eurasia, most China, Central</td>
<td>Press &amp; Herrin SIPRI (1968)</td>
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<td></td>
<td>selected on the basis of</td>
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<td>USSR, Greenland,</td>
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<td>noise &amp; geographical distribution</td>
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<td></td>
<td></td>
<td></td>
<td>N.Africa, Philip-</td>
<td></td>
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<td></td>
<td>of WWSSN</td>
<td>Australia (1)</td>
<td></td>
<td></td>
<td></td>
<td>pine Islands</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>South Pole (1)</td>
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<td>4</td>
<td>90%</td>
<td>N. America, S.</td>
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<td></td>
<td></td>
<td>Greenland (1)</td>
<td></td>
<td></td>
<td></td>
<td>America, South-</td>
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<td></td>
<td></td>
<td>N. America (7)</td>
<td></td>
<td></td>
<td></td>
<td>west Africa,</td>
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<tr>
<td></td>
<td></td>
<td>S. America (5)</td>
<td></td>
<td></td>
<td></td>
<td>Australia, North-</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>east Asia</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>29 proposed stations of</td>
<td>Asia (8)</td>
<td></td>
<td></td>
<td>3.25 &lt; M_s &lt; 3.5</td>
<td>N. America, S.</td>
<td>Press &amp; Herrin SIPRI (1968)</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>America, Southern</td>
<td></td>
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<tr>
<td></td>
<td>60 K magnification at</td>
<td>Africa (4)</td>
<td></td>
<td></td>
<td></td>
<td>Africa, India,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>selected at</td>
<td>Australia (1)</td>
<td></td>
<td></td>
<td></td>
<td>Eastern Russia,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WWSSN</td>
<td>South Pole (1)</td>
<td></td>
<td>4</td>
<td>90%</td>
<td>S.E. Asia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>locations</td>
<td>Greenland (1)</td>
<td></td>
<td></td>
<td></td>
<td>Antarctica,</td>
<td></td>
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<tr>
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<td></td>
<td>N. America (6)</td>
<td></td>
<td></td>
<td></td>
<td>Australia</td>
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<td></td>
<td></td>
<td>S. America (3)</td>
<td></td>
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</tr>
<tr>
<td>Sr. No.</td>
<td>Description of Network &amp; Data Base</td>
<td>Minimum No. of Detections</td>
<td>Interval Probability</td>
<td>Range of Magnitude</td>
<td>Regions Covered</td>
<td>Reference</td>
<td></td>
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<tr>
<td>3.</td>
<td>51 stations LP network selected from UN returns of 1970.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Basham &amp; Whitham (1971)</td>
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<tr>
<td></td>
<td>CONVENTIONAL</td>
<td></td>
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<tr>
<td></td>
<td>Asia (8)</td>
<td></td>
<td></td>
<td>3.35&lt;M&lt;3.65</td>
<td>N. America, Most of Europe, Greenland</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Europe (5)</td>
<td></td>
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<td></td>
<td>Africa (2)</td>
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<td></td>
<td>Australia (8)</td>
<td></td>
<td></td>
<td>3.65&lt;M&lt;4.0</td>
<td>Russia, Northern China, Eurasia, N. Africa &amp; Alaska</td>
<td></td>
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<tr>
<td></td>
<td>Antarctica (2)</td>
<td></td>
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<td>N. America (15)</td>
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<td></td>
<td>S. America (3)</td>
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<tr>
<td></td>
<td>New Zealand (1)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Pacific (3)</td>
<td>4</td>
<td>90%</td>
<td>4.0&lt;M&lt;4.3</td>
<td>Central Africa, South Asia, Central S. America</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>ARRAYS</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>ALP (USA)</td>
<td></td>
<td></td>
<td></td>
<td>Australia, Central Africa, &amp; S. America</td>
<td></td>
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<td></td>
<td>HPS (Sweden)</td>
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<td></td>
<td>LAO (USA)</td>
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<tr>
<td></td>
<td>NOS (Norway)</td>
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<tr>
<td></td>
<td>YKA (Canada)</td>
<td></td>
<td></td>
<td></td>
<td>Southern parts of Africa &amp; S. America</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE A2-3

Earlier Studies of the Location Capability of Various Seismograph Networks - Model Studies

<table>
<thead>
<tr>
<th>Sr. No. of Network</th>
<th>Description</th>
<th>Distribution</th>
<th>Noise amplitude (nm) range around 1 Hz (50% probability)</th>
<th>Area of 95% confidence ellipse for 4 station location (Sq. km.)</th>
<th>Source regions covered</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 44 selected stations of WWSSN</td>
<td>Asia (14)</td>
<td></td>
<td></td>
<td></td>
<td>South Asia &amp; Europe</td>
<td>Press &amp; Herrin SIPRI (1968)</td>
</tr>
<tr>
<td></td>
<td>Europe (8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Africa (7)</td>
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<td></td>
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<tr>
<td></td>
<td>Australia (1)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>South Pole (1)</td>
<td>40.0</td>
<td>2.50</td>
<td></td>
<td>All land areas except America &amp; Australia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greenland (1)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>N. America (7)</td>
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<tr>
<td></td>
<td>S. America (5)</td>
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</tr>
<tr>
<td>2. All stations above + 5 VELA Observatories + NORSAR</td>
<td>WWSSN : same as above</td>
<td>40.0</td>
<td>2.50</td>
<td></td>
<td>All land areas of the globe.</td>
<td>Evernden (1971)</td>
</tr>
<tr>
<td></td>
<td>VELA observatories in USA</td>
<td>2.50</td>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NORSAR</td>
<td>1.25</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sr. No. of Network</td>
<td>Distribution</td>
<td>Noise amplitude (2mm)</td>
<td>Area of 95% confidence ellipse for 4 station location</td>
<td>Source regions covered</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
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<td>-----------------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td>3. NANET 25-stations</td>
<td>North American network including VELA observatories &amp; LRSM stations</td>
<td>10.0 0.2</td>
<td>&gt;5000 for m_b&gt;4.5</td>
<td>All land areas except N. America</td>
<td>Evernden (1971)</td>
<td></td>
</tr>
<tr>
<td>4. 46 station CONVENTIONAL SPZ network selected from UN returns of 1970</td>
<td>Asia (7) Australia (9) New Zealand (2) N. America (7) Mexico (5) Europe (2) Africa (5) Antarctica (2) ARRAYS GBA (India) YKA (Canada) HFS (Sweden) LAO (US) NOS (Norway) WRA (Australia) EKA (UK)</td>
<td></td>
<td>&lt;500 for m_b&gt;4.5</td>
<td>All land areas of world except southern parts of Africa &amp; America</td>
<td>Basham &amp; Whitham (1971)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;500 for m_b&gt;5.0</td>
<td>Whole world except a small area in South Atlantic Ocean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE A2-4
An Earlier Study of Detection Capability based on Analysis of Real Data
The International Seismic Month Experiment

<table>
<thead>
<tr>
<th>Wave type</th>
<th>Description of Network</th>
<th>Distribution &amp; Data Base</th>
<th>Minimum No. of Detections</th>
<th>Interval Probability</th>
<th>Range of Magnitude</th>
<th>Regions Covered</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-wave</td>
<td>32 stations selected from 150 ISM stations on the basis of high observed probability for detecting teleseismic P signals</td>
<td>CONVENTIONAL STATIONS</td>
<td>Asia (9)</td>
<td>90%</td>
<td>4.2 &lt; m0 &lt; 4.3</td>
<td>Asia</td>
<td>Lacoss et al (1974)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Europe (6)</td>
<td></td>
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<td></td>
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<td></td>
<td>Africa (3)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Australia (2)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>South Pole (1)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>N. America (8)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>S. America (2)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pacific (1)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>ARRAYS (Unprocessed data)</td>
<td></td>
<td>HFS (Sweden)</td>
<td>2</td>
<td>90%</td>
<td>4.2 &lt; m0 &lt; 4.3</td>
<td>Asia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GBA (India)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>BDF (Brasil)</td>
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<tr>
<td></td>
<td>(Processed Data)</td>
<td></td>
<td>LAO (USA)</td>
<td></td>
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<td></td>
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<td></td>
<td>YKA (Canada)</td>
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<td></td>
<td></td>
<td></td>
<td>NOS (Norway)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Long period</td>
<td>46 stations selected from the ISM list on the basis of high operational sensitivity for 20 sec Rayleigh waves</td>
<td>Asia (9)</td>
<td>90%</td>
<td>3.65 &lt; m0 &lt; 3.8</td>
<td>Asia</td>
<td>Filson (1974)</td>
<td></td>
</tr>
<tr>
<td>surface wave</td>
<td></td>
<td></td>
<td>Europe (10)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Africa (2)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Australia (2)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>N. America (16)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>S. America (2)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Greenland (3)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Pacific (2)</td>
<td></td>
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</tr>
</tbody>
</table>

Note: LAO, HFS, KBL, CHG & all Canadian Stations re-read for ISM by analyst.
APPENDIX III

Appendix to chapter 5: estimated capability of the global network

The purpose of this appendix is to give a more complete description of the capability estimation procedures and results discussed in chapter 5.

Detection capability estimation model

The basic scientific assumptions and definitions of the estimation model used are given in table A5-I. It is assumed (equation A5-1) that the seismic size or magnitude parameter is estimated according to some well-defined and well-accepted rule. Although the computer programmes that evaluate the model are based on magnitude, network capabilities in terms of ground motion may be estimated through conversion of the magnitude formula. The second fundamental scientific assumption is that the logarithms of seismic signals and noise at a given station may be approximated by normal distributions (equations A5-2 and A5-3). In equation A5-2, \( P_{ij} \) is the probability that station \( i \) will detect event \( j \) of magnitude \( m_j \). The term \( \hat{P}_j(k) \) in equation A5-4 is the probability that \( k \) stations will detect event \( j \) and \( \hat{P}_j(\geq \alpha) \) is the probability that \( \alpha \) or more stations will detect event \( j \). A desired network detection probability based on detections at \( \alpha \) stations is specified and \( \hat{P}_j(\geq \alpha) \) is computed at each geographic node (\( j \)) for a low starting \( m_b \) which is incremented to higher values until the network threshold is met or exceeded.

Whenever, at a given node and a given \( m_b \), \( \hat{P}_j(\geq \alpha) \) is equal to or greater than the desired network detection probability, that \( m_b \) is assigned to that geographic node as the lower network detection capability. Other parameters required for evaluating the network detection capability are given in table A5-I and some of these are discussed below:

\( A_{ij} \) - this is the expected amplitude at station \( i \) for an event \( j \) at a given distance, \( \Delta ij \), and magnitude \( m_j \). Freedman (1967) showed that the amplitude distribution of body wave recordings closely approximated a log-normal distribution. The amplitude-distance relationships used in this study are due to Gutenberg and Richter (1956) and Veith and Clawson (1972). At teleseismic distances there are no essential differences in these curves (see figure A5-7); however the latter usually yields smoother capability contours. No \( P' \) or core phases are considered in these analyses.

\( E_{ij} \) - this allows for the inclusion of station-epicentre bias corrections; however, in the present study this correction was set to zero in all cases.

\( \mu N \) - this is the mean of the \( \log_{10} \) zero to peak noise measurements at a given station in the frequency band of the expected signal. It is best estimated through the geometric mean of impulsive or signal-like noise features and this mean may be a function of time-of-day or the season. Estimates of this parameter using the \( \log_{10} \) of the arithmetic mean or the root-mean-squared (RMS) of noise measurements are less useful than those based on the geometric mean. These are the most important parameters bearing on the results of any network capability study.
\( \sigma_n^2 \) - this is the variance in the \( \log_{10} \) noise measurements. Although we do not have adequate measurements of this parameter the following scheme was used to assign greater variance to stations with higher noise levels.

<table>
<thead>
<tr>
<th>Amplitude (a in nanometers)</th>
<th>Standard deviation (in magnitude units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a \leq 1.0 )</td>
<td>0.15</td>
</tr>
<tr>
<td>3.0</td>
<td>0.20</td>
</tr>
<tr>
<td>4.0</td>
<td>0.30</td>
</tr>
<tr>
<td>5.0</td>
<td>0.40</td>
</tr>
<tr>
<td>5.0 &lt; a &lt; 10.0</td>
<td>0.45</td>
</tr>
<tr>
<td>10 &lt; a</td>
<td>0.50</td>
</tr>
</tbody>
</table>

\( \sigma_s^2 \) - this is the variance of the \( \log_{10} \) (signal amplitude), or magnitude, measurement. A signal standard deviation of 0.2 magnitude units was used in all the following analyses.

\( \phi(x) \) - the cumulative probability or distribution function of the normal distribution.

\( N \) - the number of stations in the network.

SDT - the estimate of the signal-to-noise ratio required at stations of the network or to declare or recognize a detection. Given that the other input parameters \( S/N \) to the network estimation procedure remain the same, the change in network threshold magnitude \( (\delta m_b) \) from \( SDT_1 \) to \( SDT_2 \) is \( \delta m_b = \log_{10} (SDT_2/SDT_1) \).

The results of this method are contoured maps of \( m_b \) which give the network threshold magnitude for the specified probability, \( P_j \) \(( \geq \)\), based on detections at \( \geq \) or more stations.

**Short period detection results**

The model described above was applied to the various networks and associated station noise levels specified in chapter 4 of this report. The results of these analyses are given below in the form of contour maps. Following each map, in cases where there has been a significant change of input parameters, a complete listing of those parameters is given in the form of a table. The detection capability estimates (figs. A5-1 through A5-5, and A5-7) are given as world maps contoured in terms of the lowest magnitude \( (m_b) \) at which there is a 0.90 probability that at least four stations of the network will detect a surface seismic event at a given signal-to-noise \( (S/N) \) ratio. The amplitude-distance relation of Veith and Clawson (1972) was used in these analyses and the effect of a different relationship of this type will be discussed below.

A summary of the presentation of these results is as follows:
A comparison of the Veith and Clawson (1972) and Gutenberg and Richter (1956) magnitude correction factors is given in figure A5-6. These factors are essentially the same at distances greater than 20°; however the former is a smoother function and yields capability maps which are more easily contoured. The capability diagram shown in figure A5-7 was generated with exactly the same model parameters as that shown in figure A5-2 except for the use of the Gutenberg-Richter magnitude factors in the former and Veith-Clawson in the latter. There are only slight differences in the two estimates.

Many of the stations that make up the networks studies above routinely report seismic readings to the International Seismological Center at which bulletins or lists of epicentres, origin times, and magnitudes are prepared and published. These reports and bulletins give us an opportunity to check our detection capability estimates. Figures A5-8, A5-9 and A5-10 show the distribution, as a function of magnitude, of the number of seismic events for which at least four stations of each of the networks (SP-I, SP-II and SP-III) reported magnitudes to the ISC during 1970-1973. The general pattern of seismicity is that events of smaller magnitude are more numerous; however, these smaller events are more difficult to detect. This accounts for the increase and then decrease, as magnitude decreases, of the number of events reported to the ISC from the three networks; as seen in figures A5-8 through A5-10. For example, in figure A5-9 it may be seen that fewer events in the northern hemisphere of magnitude 4.5 were reported to the ISC by at least four stations of network SP-I than events of magnitude 4.6, yet figure A5-2 predicts that there is a 0.90 probability that all events above magnitude 4.4 in the northern hemisphere will be detected by at least 4 stations of network SP-I. The estimated detection capabilities of each of the existing networks (SP-I, SP-II and SP-III) are greater than can be confirmed by data reported to the ISC during 1970-1973. These discrepancies are due to present reporting procedures of the ISC and the idealized assumptions inherent in our estimation schemes.

**Location capability estimation model**

Epicentre location is usually determined by an iterative procedure which successively minimizes, in a least-squares sense, the differences between observed arrival times at a number of stations and calculated arrival times at those stations.
based on an initial assumed location and origin time and an empirical propagation
time-distance relationship (see Bolt (1960)). The results of such calculations are
estimates of origin time, latitude, longitude, depth, and the errors associated with
these quantities. A discussion of seismic event location procedures is given in
section 3a of this report. For a fixed depth, the errors associated with latitude
and longitude estimates are expressed in terms of the lengths and directions of
maximum and minimum location uncertainty which are the semi-major and semi-minor
axes of an ellipse (see Flinn (1965)). That is, there will be a probability $P$ that
the true epicentre lies within the elliptical area described by the length and
orientation of these axes. In practice, epicentre location accuracy is a function
of the number of stations in and distribution of the recording network, the station
signal-to-noise ratio and accuracy in measuring onset time at individual stations,
and errors in the assumed propagation time-distance relationship.

Location capability results

In these studies it was assumed that a magnitude ($m_b$) 5.0 event occurred at
the earth's surface at each node of a grid spaced 15° in latitude and longitude.
The 1968 Herrin travel-time tables and estimated standard deviations of these tables
based on a reduction by two thirds of the values given by Veith and Clawson (1972,
see figure A5-11) were used. A uniform standard deviation of travel time
measurement of 0.5 seconds at each station was assumed. Other estimation procedure
parameters for the three short-period networks are the same as given in tables A5-2,
A5-3, and A5-4. It was required that the subset of stations used in the location
analysis make up a network with the maximum number of stations with at least a
0.9 probability of detecting the event. The results of the analyses are contoured
world maps showing the length of the semi-major axis of the ellipse within which
there is a 0.95 probability of an event, which occurred at a node, being located by
the detecting network. This procedure gives an estimate of the maximum epicentral
error range which could be expected in the network location of a magnitude 5.0
event. For probabilities of 0.90, 0.75 and 0.50 the length of the maximum axis of
the accuracy or error ellipse is reduced by factors of 0.75, 0.50 and 0.25
respectively.

The results of this epicentre location error analysis method, when applied to
networks SP-I, SP-II and SP-III, are given in figures A5-12, 13 and 14 respectively.

Figures A5-15, A5-16, and A5-17 show estimates of the capability of the networks
SP-I, SP-II and SP-III to determine the depth of a seismic event based on initial
arrivals alone. Contoured on the world maps of these figures are the depths above
which there is a 0.95 probability that an event of magnitude 5.0, which occurred at
the surface, would be located.

Figures A5-18 and A5-19 show the effects of different magnitude-distances and
travel time-distance relationships on the location capability estimation procedures.
The model parameters used in figures A5-12 and A5-18 were the same except that the
Gutenberg and Richter (1956) factors, vice Veith and Clawson, were used in the
analysis that resulted in figure A5-18. The model parameters used in figures A5-18
and A5-19 were the same except the Jeffreys-Bullen, vice Herrin 1968, travel-time
tables were applied in figure A5-19. The differences in figures A5-12 and A5-18
are evident but not significant; the differences between figures A5-18 and A5-19
are barely discernible.
Capability to obtain identification parameters

The most widely accepted identification parameter for which we have the capability to model a network detection threshold is surface wave magnitude or $M_s$. This has been done using the procedure outlined above for short period detection and surface wave magnitude relationships for three long period networks. The surface wave magnitude formulas used are:

$$M_s = \log_{10}(2A/T) + 1.66 \log_{10}A \text{ for } A > 25^\circ$$

and

$$M_s = \log_{10}(2A/T) + \log_{10}A + 0.92 \text{ for } A \leq 25^\circ$$

In these formulae $A$ is the maximum Rayleigh wave amplitude (o-p) in nanometers of ground motion with period $T$ near 20 seconds ($18 < T < 22$). The results of this detection modelling are given below. Other surface wave magnitude determination procedures have been suggested, e.g. Marshall and Basham (1971); however, because these require corrections for specific paths, it is impossible to apply them in the existing detection model.

Some members of the GSE have pointed out that certain short period measurements, other than magnitude, have been useful in identification of seismic source type. These include such measurements as complexity, spectral ratio, and the results of various digital filters. It is difficult to accurately model the capability of a network to measure these parameters; nevertheless, an attempt to do so has been made by applying the short period detection model previously described. In this attempt a hypothetical network of digitally recording stations, SP-III (SR0), is used and higher signal-to-noise ratios ($S/N$) are required so that the signals may not only be detected but used in data processing schemes for identification. We have also required that the stations be greater than 2,200 km from the epicentre to avoid the complicated propagation paths at shorter distances.

Long period results

The long period detection results are given in a series of world maps with contours showing the surface wave magnitudes ($M_s$) of seismic events that will have a 0.9 probability of being detected by at least four (or in one case two) stations of each of the long period networks given in chapter 4. The presentation of the long period detection results is summarized as follows:

<table>
<thead>
<tr>
<th>Figure</th>
<th>Table</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5-20</td>
<td>A5-6</td>
<td>Network LP-I, 0.9 probability, 4 stations $S/N = 2.0$.</td>
</tr>
<tr>
<td>A5-21</td>
<td>see A5-6</td>
<td>Network LP-I, 0.9 probability, 2 stations, $S/N = 3.0$.</td>
</tr>
<tr>
<td>A5-22</td>
<td>A5-7</td>
<td>Network LP-II, 0.9 probability, 4 stations, $S/N = 2.0$.</td>
</tr>
<tr>
<td>A5-23</td>
<td>A5-8</td>
<td>Network LP-III, 0.9 probability, 4 stations, $S/N = 2.0$.</td>
</tr>
<tr>
<td>A5-24</td>
<td>A5-9</td>
<td>Network LP-III (SR0) 0.9 probability, 4 stations, $S/N = 2.0$.</td>
</tr>
</tbody>
</table>
The final long period analysis listed above is based on the assumption of SRO equipment operating at each site of network LP-III.

**Short period results**

Examples of estimates of the global capability of an all digital recording network to achieve detection conditions considered suitable to obtain short period identification parameters, are given in figures A5-25 and A5-26. The presentation of the results are summarized as follows:

<table>
<thead>
<tr>
<th>Figure</th>
<th>Table</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5-25</td>
<td>A5-10</td>
<td>Network SP-III (SRO) 0.9 probability, 4 station detection, S/N = 3, distance greater than 2,200 km.</td>
</tr>
<tr>
<td>A5-26</td>
<td>see A5-10</td>
<td>Network SP-III (SRO) 0.9 probability, 2 station detection, S/N = 10, distance greater than 2,200 km.</td>
</tr>
</tbody>
</table>
\[
\log_{10} A_{ij} = m_j + b_\Delta + c_\Delta \log_{10} A_{ij} + E_{ij}
\]

\[
P_{ij} = \Phi \left[ \frac{\log_{10} A_{ij} - (\mu_N + \log_{10} SDT)}{\left(\sigma_n^2 + \sigma_s^2\right)^{1/2}} \right]
\]

\[
\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-y^2/2} \, dy
\]

\[
\hat{P}_j(\geq \alpha) = \sum_{k=\alpha}^{N} \hat{P}_j(k)
\]

Symbols above are defined as follows:

- \( A_{ij} \) - signal amplitude at station \( i \) for event \( j \) (0-p)
- \( m_j \) - magnitude of event \( j \) (m
- \( b_\Delta, c_\Delta \) - standard table entries
- \( E_{ij} \) - station-epicenter bias corrections
- \( \mu_N \) - mean \( \log_{10} \) noise amplitude (0-p)
- \( \sigma_n^2 \) - variance of \( \log_{10} \) noise
- \( \sigma_s^2 \) - variance of \( \log_{10} \) signal
- \( \Phi(x) \) - normal cumulative probability function
- \( N \) - number of stations in the network
- \( \hat{P}_j(k) \) - probability that \( k \) stations will detect event \( j \)
- \( \hat{P}_j(\geq \alpha) \) - probability that \( \alpha \) or more stations will detect event \( j \)
- \( SDT \) - station detection threshold; i.e., signal-to-noise ratio required for detection at station.
- \( \Delta_{ij} \) - epicentral distance from station \( i \) to event \( j \).
- \( P_{ij} \) - probability that station \( i \) will detect event \( j \).

Table A5-1. Basic equations and definitions used in detection estimation.
Figure A5-1. Estimated short period detection capability of Network SP-I in terms of $m_b$ based on 0.9 probability of detection at at least four stations with a S/N of 1.5.
Table A5-2. Station and estimation procedure parameters used in generating Figure A5-1. (Network SP-I).

Note: The sign conventions for LAT and LONG for all station parameter tables are Lat N positive, Long W positive.
Figure A5-2. Estimated short period detection capability of Network SP-I in terms of $m_b$ based on 0.9 probability of detection at at least four stations with a S/N of 3.0.
Figure A5-3. Estimated short period detection capability of Network SP-II in terms of $m_o$ based on 0.9 probability of detection at at least four stations with a S/N of 1.5.
### Station Table

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Table A5-3. Station and estimation procedure parameters used in generating Figure A5-3. (Network SP-II)
Figure A5-4. Estimated short period detection capability of Network SP-III in terms of $m_b$ based on 0.9 probability of detection at at least four stations with a $S/N$ of 1.5.
Figure A5-5. Estimated short period detection capability of Network SP-III (SRO) in terms of $m_b$ based on 0.9 probability of detection at at least four stations with a $S/N$ of 1.5.
Table A5-4. Station and estimation procedure parameters used in generating Figure A5-4. (Network SP-III).
Figure A5-6. Comparison of Veith and Clawson (1972) and Gutenberg and Richter (1956) magnitude ($m_b$) factors.
Figure A5-7. Detection capability of Network SP-1 in terms of $m_b$, based on 0.9 probability of detection at least four stations, a S/N of 1.5, and the Gutenberg-Richter (1956) $m_b$ factors.
Figure A5-8. Detection capability of Network SP-I based on $m_b$ reported to the ISC from at least four stations during 1970-1973.
Figure A5-9. Detection capability of Network SP-II based on $m_b$ reported to the ISC from at least four stations during 1970-1973.
Figure A5-10. Detection capability of Network SP-III based on \( m_b \) reported to the ISC from at least four stations during 1970-1973.
Figure A5-11. P wave travel time standard deviations used in network location capability estimates.
Figure A5-13. Estimated capability of Network SP-II to locate surface event of $m_p$ 5.0. Contours represent length (in km) of semi-major axis of 95% confidence ellipse.
Figure A5-14. Estimated capability of Network SP-III to locate surface event of $m_b$ 5.0. Contours represent length (in km) of semi-major axis of 95% confidence ellipse.
Figure A5-15. Estimated depth determination capability of Network SP-I for a surface event of $m_D 5.0$. Based on initial $P$ arrivals only, there is a 0.95 probability that a surface event will be located within the depth contoured (in km).
Figure A5-16. Estimated depth determination capability of Network SP-II for a surface event of $m_b$ 5.0. Based on initial P arrivals only, there is a 0.95 probability that a surface event will be located within the depth contoured (in km).
Figure A5-17. Estimated depth determination capability of Network SP-III for a surface event of $m_b$ 5.0. Based on initial P arrivals only, there is a 0.95 probability that a surface event will be located within the depth contoured (in km).
Figure A5.18. Estimated capability of Network SP-I to locate surface event of $m_b$ 5.0. Contours represent length (in km) of semi-major axis of 95% confidence ellipse. This diagram was generated using Gutenberg and Richter (1956) magnitude factors.
Figure A5-19. Estimated capability of Network SP-I to locate surface event of \( m_s \) 5.0. Contours represent length (in km) of semi-major axis of 95\% confidence ellipse. This diagram was generated using the magnitude factors and the Jeffreys-Bullen travel time tables.
Table A5-6: Station and estimation procedure parameters used in generating Figure A5-20. (Network LP-1).
Figure A5-21. Estimated detection capability of Network LP-I in terms of $M_o$ based on 0.9 probability of detection at at least two stations with a S/N of 3.0.
Figure A5-22. Estimated detection capability of Network LP-II in terms of \( M_a \) based on 0.9 probability of detection at at least four stations with a S/N of 2.0.
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Table A5-7. Station and estimation procedure parameters used in generating Figure A5-22. (Network LP-II).
Figure A5-23. Estimated detection capability of Network LP-III in terms of $N_\theta$ based on 0.9 probability of detection at at least four stations with a S/N of 2.0.
### Table A5-8. Station and estimation procedure parameters used in generating Figure A5-23. (Network LP-III).
Figure A5-21. Estimated detection capability of Network LP-III (SRO) in terms of $M_0$ based on 0.9 probability of detection at least four stations with a $S/N$ of 2.0.
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Table A5-9. Station and estimation procedure parameters used in generating Figure A5-24. (Network LP-III (SR0)).
Figure A5-25. Estimated short period detection capability of Network SP-III (SRO) in terms of \( m_0 \) based on 0.9 probability of detection at at least four stations at distances greater than 2200 km with a S/N of 3.0.
Table A5-10. Station and estimation procedure parameters used in generating Figure A5-25. (Network SP-III (SRO)).
Figure A5-26. Estimated short period detection capability of Network SP-III (SRO) in terms of $m_b$ based on a 0.9 probability of detection at least two stations at distances greater than 2200 km with a S/N of 10.0.
APPENDIX IV

Appendix to chapter 7: description of some existing data centres

The purpose of this appendix is to give a more complete description of some of the data centres considered in chapter 7. The following are factual descriptions related to problems of interest to the Ad Hoc group, and do not imply any commitment of these resources to the services of a global co-operative system.

THE INTERNATIONAL SEISMOLOGICAL CENTRE (ISC), NETTIBURY, UNITED KINGDOM

Purpose

The task of the ISC is to process epicentral data dispatched to it from all over the world. These data consist both of observations of earthquakes and preliminary epicentral estimates. All station readings and the results of the processing are compiled in a bulletin of basic earthquake parameters in chronological order and dispatched to contributors and subscribers.

Data sources

Referring to figure A7-1, the input data come in a number of forms:

(i) Pre-punched cards from stations

(ii) Magnetic tapes from networks of stations

(iii) Station bulletins and other written material, for example from air letters

(iv) Paper tape both by post and by the world-wide dialled telex network

(v) Data sheets which have been filled up by stations and in some cases by networks.

These input forms naturally divide themselves into two categories, the computer readable and the non-computer readable. The computer readable data pose practically no problem as the computer installation to which the Centre has access, the Rutherford High Energy Laboratory (RHEL) near Chilton, Oxfordshire, possesses input devices for almost every conceivable sort that is now, or ever has been, used.

Pre-punched cards in general come from individual stations with some computer equipment or from small networks, for example, German Democratic Republic with a network of about three stations, and the Strasbourg network. Magnetic tapes come from the larger networks of stations, for example, from Japanese, Australian, Canadian and Russian networks. The United States Geological Survey also sends its results and observations on magnetic tape. Paper tape comes by post from small networks and is chosen for economic reasons. At present only the Copenhagen and New Zealand networks use it. Four networks are now reporting by telex, and it is assumed that more will follow soon. This is an exceedingly fast means of
communication and has the advantage that it can be triggered, that is to say, that a message can be sent to the station asking it for particular observations.

Many stations still report their observations, even their epicentral estimates, on post cards, station bulletins and air letter forms. This category causes the greatest problems because not only must these data be converted into computer readable form, but also a uniform format must be accomplished.

**Procedures**

Within a few days of receipt all input data are sent to the computer installation and are run through a reformat-storage program. This program converts all data into a common format, which is used throughout the rest of the processing, and stores the entries on a disk file with the capacity of 200 megabytes or about three years of all data received. For safety's sake a back-up tape copy of this file is made periodically before any of the original input data are destroyed. The file is arranged in station-month "packets"; within each packet the observations and epicentral estimates are stored chronologically. This program at present is run two or three times a week, but since it requires very little computer time (seconds), it could be run hourly or daily as required. It will also print out various types of statistics, e.g., a table of contents by stations and months and number of observations received, or alternatively, by networks. This allows the data flow to be checked so that no gaps exist in it. This is particularly important for regular production since the primary objective of the ISC bulletin is completeness.

At regular intervals this data collection file can be put through an input processor program which will produce a tape containing all observations and epicentral estimates within any given period contained on the disk file and sort it into chronological order. The program does not affect either the contents of the data collection file or the way in which it is stored. The period of time covered in the output file can be any period from seconds to, what is currently used, one month; it could be as much as six months if necessary. This particular program was designed deliberately to enable the ISC to provide a fast location service if so required by its Governing Council.

Once a chronological order data tape has been produced the process of revising rough estimates of epicenters and finding new ones begins. The first process is to revise all the events for which estimates are available. This would usually include all of the large events and some small ones from particularly good networks. The process takes place in three stages:

(i) First, all observations which could conceivably belong to a particular event are grouped together

(ii) A preliminary suppression of contamination (i.e., misplaced observations) takes place

(iii) Subsequently, the event is relocated and simultaneously a second decontamination process is applied.

By fixing focal parameters, searching for depth-sensitive phases and eliminating contamination the revision program will automatically come to the best solution that it can. This is recorded on the output tape after a process of phase
identification for those observations beyond 25 degrees. A print-out is also provided for the editor (a seismologist) who can control the operation of the revision program manually. He will check the results for obvious anomalies such as large earthquakes in aseismic areas, earthquakes in the air, deep earthquakes where deep earthquakes have never been observed before, and so forth. He can also further eliminate contamination.

The contamination can be classified into a few categories. First, and most prevalent, is the near duplicate observation. These reach the Centre through different reporting routes. For example, the Australian network reports some of their stations to the United States Geological Survey PDE service via telex and air letter. Later they read their own records again in light of the PDE epicenter and send those data directly to the ISC. The result of this is that the input tape contains two observations for the same station of the same earthquake, with slightly different onset times. Most of this sort of contamination is removed automatically during the revision process, but some must be deleted by hand. A second category is an (as yet) unknown earthquake happening at just the right moment so that its observation is not too unreasonable to be included in another event. This sort is particularly difficult to weed out automatically and must be left to the editor's judgement for manual removal.

Another sort of contamination is the plain mistake where there has been a punching error or an error in reading the time from a record. Mistakes of days, hours, minutes and even months are not at all uncommon and give rise to very peculiar results on the first pass.

The above process is repeated about three times before the program to find earthquakes is attempted. This program searches throughout all of the unassociated observations (that is, all the observations which are not associated with the events found so far) to find new ones. It uses the same algorithm as used by the NEIS in its PDE service, although a start has been made to improve it for ISC purposes.

Once the input processor sorts the data into chronological order, the ordering of the observations and estimates are never changed other than to insert new or revised estimates and observations. An elaborate series of tags and flags is used to mark each record as either belonging to a particular event, belonging to the unassociated data stream or as having been deleted. Tags are also used to say that an observation was dissociated with an event and that on further processing should never be associated with it. In addition all of the observations within a particular event are "chained" together in order of epicentral distance. When new events have been found, they are immediately revised and the editor is again provided with a suitable print-out. At this stage rather a large number of fallacious events are produced which must be manually deleted. This amounts to perhaps as much as a third or half of all the new ones found.

Although at present the program to find new events is only run once, and that only after all existing events have been revised, there is no reason why this should be other than convenience. Performing additional runs would be particularly easy if the data base were much smaller. At present, after a two-year wait for data, between 50,000 and 100,000 observations are processed each month. If the waiting period were to be only a week or two, and the data base limited to key stations, the entire process could be run hourly rather than monthly. This is
because permanently mounted disks could be used for the input and output data sets and the editing input could be done on-line. Only minor additions in equipment and staffing would be necessary to accommodate such a service at the ISC.

**Plans for 1977**

By the end of February 1977 the RHEL central computer will possess just under double the computing power it now has. As a consequence the ISC is now being encouraged to install a remote job entry (RJE) terminal in its Newbury headquarters. An RJE is a minicomputer used primarily as a message switching and inter-leaving processor. It allows one to have several input and output devices to run apparently simultaneously at a remote location down a single private telephone line. The ISC is planning to buy one which will allow the use of three remote interactive terminals (like teletypewriters) operating at 30 characters a second, a 200 line a minute line printer, console teletypewriter at 10 characters a second, which can also be used as a remote terminal as well as receiving and transmitting control messages to the central computer, and either a card or paper tape reader. All punched cards are to be eliminated from the system, so a card reader is not required. A universal paper tape reader would be purchased if a rapid service were to be requested. One of the remote terminals envisaged with this system is a Texas Instruments model 742 "intelligent" teletypewriter. It contains a 12,000 byte memory and can be programmed to facilitate data entry procedures. It can perform such things as a double-entry validity checking, sequence checking, partial formatting, and so forth. Its acquisition will mean that instead of punching cards and then transporting them to the computer, data arriving at the Centre in visual form would be translated into computer readable form within a matter of minutes rather than hours or days. This is a particularly crucial stage in the data processing scheme in that it is a serial process which can only be as quick as the longest element in the chain.

With these minor developments to the existing system, data for an event arriving on one day would be processed to bulletin form and in the post on day three. Given that most of the data come by air letter from areas outside Europe and by telex in Europe, one additional seismologist and two additional clerical assistants could provide a service which reached the customer in less than one month.
Figure A7-1 Schematic view of the data analysis procedures at the International Seismological Centre (ISC).
Purpose

The National Earthquake Information Service (NEIS) uses seismic data from world-wide sources to compute and publish epicenter locations, a few weeks to a few months after the event. Data are received by telegram, direct computer link, air mail and other modes. In addition, a network of seismographic stations, expanding to cover most of the United States, is telemetered to Golden, Colorado.

Data sources

NEIS receives data from a majority of the countries in the world. The most rapid to arrive are from the US Network in the form of analog paper and film, recorded in real-time at the NEIS office in Golden, Colorado. Four 14-channel digital and three 9-channel FM telemetry systems bring in about 53 short period vertical and 8 long period channels of data. The present distribution of stations permits detection and location of significant or potentially destructive world-wide earthquakes larger than Richter magnitude 6, and detection of most earthquakes that are felt in the conterminous 48 states. The principal institutions contributing real-time data via this network are the Universities of Washington, California (Berkeley), Nevada, Utah, and South Carolina, California Institute of Technology, United States Geological Survey (Menlo Park), California Department of Water Resources, St. Louis University, Virginia Polytechnic Institute, the Bureau of Reclamation, Energy Research and Development Administration and other government agencies.

Data from international sources arrive within one day to two weeks in the form of telegrams and computer links. Selected station data are sent promptly to the seismic Data Analysis Center (SDAC) for rapid bulletins. Error correction and additional data entry are performed later at the NEIS. The entire Canadian standard network data are written on a computer file in Ottawa for use by the NEIS. Moreover, data from the Norwegian array NORSAR are transmitted to an ARPANET computer at the University of Southern California, Information Services Institute. From both of these computers, the NEIS copies and edits data twice weekly. United Kingdom array data are transmitted bivweekly via ARPANET from London.

Services

Seismic data from all sources are merged into a chronological list of seismic phase arrival times, periods and amplitudes for about 2,000 different seismograph stations. Total phase data volume is about 45,000 station readings (first arrivals) per month. From this base, the NEIS compute about 6,000 epicenters each year, each one using from 5 to 600 stations in the location, depending on the magnitude and location of the event. About 60 per cent of the phase data remain unassociated with events. The epicenters and their parameters are published in "Preliminary Determination of Epicenters" (PDE) and "Earthquakes in the United States". Complete data for each event are listed in much larger publications, such as the Earthquake Data Report. Additional publications of the NEIS include
seismicity maps, "Seismological Notes" in the Bulletin of the Seismological Society of America, and directories of world-wide seismograph station abbreviations and co-ordinates.

Improvements to all these services are planned.

THE EUROPEAN-MEDITERRANEAN SEISMOLOGICAL CENTRE (EMSC)

Purpose

During July 1975 the President and the Secretaries of the European Seismological Commission (ESC) initiated a project for rapid determination of the foci of earthquakes occurring in the European-Mediterranean region within a time interval of about 24 hours. Subsequent discussions pointed out that in addition to the 24 hour service, there is a need for more precise results, obtained with a greater number of stations, within a few weeks. This is the background for the creation of EMSC at Strasbourg, France, effective from 1 January 1976.

The objectives of the Centre are:

(i) to initiate a system of rapid preliminary determination of European and Mediterranean epicentres (within a few days, in special cases, within a few hours) and to transmit the results in answer to humanitarian and scientific needs

(ii) to make more accurate estimates of these epicentres from a maximum of data and to transmit the results with least possible delay

(iii) to gather all seismological data needed for the functioning of the Centre under a unified and directly accessible form in order to promote their processing

(iv) to secure and increase the data exchange with other national, regional and world data centres.

Geographical area

The geographical area covered by these objectives is limited as follows:

- to the west : by the Mid-Atlantic Rift, north of the 30°N parallel
- to the north : by the Arctic Ocean
- to the east : by the Ural Mountains and the countries bordering the Caspian, the Black and the Mediterranean Seas (included)
- to the south : by the coastal countries of the Mediterranean Sea (included)

Services

When using rapid transmission means such as Telex with immediate computer access, the delay may be from a few hours to two or three days, and thereby provide for the following services:
- information of Governments about needs for civil protection
- information of the public through press, broadcasting and television
- the alerting of scientist teams for studying the seismic activity near the epicenter immediately following the large earthquakes for attempting to predict aftershocks.

Stations or station networks without facilities for rapid transmission of data transmit by postal services. Consequently the arrival of data at the centre spans an interval of 2 to 3 weeks. When included in the computations these data (after a few weeks' delay) lead to more reliable results.

As a matter of policy data transmission should aim at formats and media directly usable by computers. Such a practice would accelerate the processing considerably and minimize human errors.

The following specific services and time scales of earthquake source parameter determinations are offered by the EMSC:

(i) **Accelerated determinations: delay of a few hours**

On requests for a specified earthquake or a set of earthquakes the EMSC interrogates stations or station networks equipped with telex. As soon as the number of received data are sufficient, the results are transmitted to the requesting agency. As the quantity of data grows, new computations are made and the modified results transmitted if required.

(ii) **Rapid determinations: delay of 3 to 4 days**

Experience shows that the most satisfactory cycle for reception of data and transmission of results is twice a week. For earthquakes with high magnitude or having caused damage, the EMSC forward the results by priority to the agencies of the countries concerned. Data collected by the EMSC are generally the same as those forwarded to the NEIS. Results on extra-European events can be transmitted on request, but they are of course less accurate than those for Europe.

(iii) **Delayed determination: delay of 3 to 4 weeks**

In order to take into account the data arriving at the EMSC by air and surface mail, the EMSC carry out new computations and transmit the results on individual punched cards. Post by surface and air mail is sent to all contributing agencies and to all other determination centres.

(iv) **Transmission of all data: delay of 6 months**

A quarterly transmission by postal services of all data implicit in (iii) is made in the form of computer listings comprising supplementary information such as macroseismic data. Unless there are exceptional circumstances, new computations will not be carried out thereafter. There are no bulletins equivalent to that of the International Seismological Centre.
(v) **Other services**

Copies of listings of particular earthquakes are available on request. Moreover, the data mentioned under (iv) can be dispatched on magnetic tape to interested parties. Finally, off-line computations, for example epicenter determinations under peculiar conditions and focal mechanisms, may be carried out on request.

The EMSC works in very close co-operation with the other international centres such as the ISC and NEIS. Financially, the EMSC is at present supported mainly by France, but other European countries have been approached to share the financial burden.

As of January 1977 a total of 32 seismological organizations in 21 countries were contributing data to the EMSC.

**THE REGIONAL SEISMOLOGICAL CENTER FOR SOUTH AMERICA (CENTRO REGIONAL DE SISMOLOGIA PARA AMERICA DEL SUR - CERESIS)**

**Purpose**

The Centro Regional de Sismología para América del Sur' (CERESIS) was established under a bilateral agreement between UNESCO and Peru in 1966, with headquarters in Lima, Peru. The Center was transferred entirely to South American countries in 1971 according to a multinational agreement. Presently, the supporting members are: Argentina, Bolivia, Colombia, Ecuador, Trinidad and Tobago, Uruguay and Venezuela. The Center is governed by a Council, an Executive Director and an Adjoint Director.

The main objectives of CERESIS is to co-ordinate, promote and sponsor seismological research and studies that will increase seismological knowledge in South America and help to take preventive measures against earthquakes to occur in member States.

**Services**

The main services provided by CERESIS are as follows:

(i) to operate a radio communication system among member States for data and information exchange, especially after large earthquakes occurring in the region

(ii) to act as a spare parts supply centre for the WWSSN in South America (under special agreement with USGS)

(iii) to provide seismological data exchange, publication of regional seismic catalogues, computer programs exchange

(iv) to organize seminars and formal seismological courses and lectures

(v) to maintain a regional library of seismic records; i.e., hard copy records and microfilm. The oldest record is from La Paz station, Bolivia, of 1913
(vi) to provide logistical support to international seismological experiments, and expert missions after destructive earthquakes

(vii) to provide computer time (limited), office space and local logistical support for visiting scientists to the Center.

Operational aspects

The present and planned operational aspects relevant to detection and identification of seismic events are:

(i) to assist member States to process seismic data from local and national nets by encouraging computer programs exchange among members and/or CERESIS, and to provide the necessary technical assistance

(ii) to co-ordinate routine seismic data transmission to CERESIS of seismic events in the region, to determine hypocentral co-ordinates of these events and to publish the data and results in a periodical bulletin

(iii) to intensify the rate of data exchange between South America seismological stations or agencies and the World Data Processing Centers, e.g., NEIS, ISC, etc.

(iv) to establish a Continental Seismic Net via satellite. This net would include additional stations in islands in the east Pacific Ocean, e.g., Easter Islands (Chile), Galápagos Islands (Ecuador), etc.

(v) to co-ordinate the implementation of regional projects for seismicity studies and seismic risk evaluations with participating international agencies.
Purpose

The Seismic Data Analysis Center (SDAC) is the focal point for the seismic verification research programme sponsored by the United States Government. The objectives of the SDAC are:

(i) to record, analyse, store and distribute seismic data from earthquakes and underground explosions

(ii) to conduct research in seismology which will lead to improved capability to detect, locate and identify seismic events and to increase understanding of the physical phenomena governing these capabilities, and

(iii) to design, develop and implement data management, processing and analysis techniques for more useful and efficient application of seismic network data to the problems of test ban monitoring and verification.

Data Sources

The research data available at the SDAC from various sources are described below.

(i) Large Aperture Seismic Array (LASA)
   Transmission: real-time via leased telephone lines.
   Short period: 13 subarray sums, vertical component, 6 beams, both sampled at 10 Hz.
   Long period: 3 component data from 10 sites sampled at 1 Hz.

(ii) Norwegian Seismic Array (NORSAR)
   Transmission: real-time via ARPANET.
   Short period: 3 subarray sums, vertical component sampled at 10 Hz.
   Long period: 3 component data from seven sites sampled at 1 Hz.

(iii) Alaskan Long Period Array (ALPA)
   Transmission: real-time via leased telephone lines.
   Long period: 3 component data from seven sites sampled at 1 Hz.
(iv) **Iranian Long Period Array (ILPA)**

Transmission: detection data daily via teletype, waveform data through physical transfer on magnetic tapes.

Short period: data from seven sites recorded locally on film. Film is read locally and detections transmitted daily to SDAC via teletype.

Long period: 3 component data from seven sites sampled at 1 Hz.

(v) **Seismic Research Observatories (SROs)**

Transmission: Physical transfer of magnetic tape from Albuquerque Seismological Laboratory.

Short period: Vertical component of specific detections sampled at 20 Hz.

Long period: 3 component data sampled at 1 Hz.

In addition, the SDAC serves as the data library for short term and discontinued projects. These include the Long Range Seismic Measurement project, the VELA arrays (TFO, UBO, CPO and BMO), the Special Data Collection System, and data for special studies from other sources such as the Worldwide Standard Seismograph Network.

**Procedures**

The data processing facilities at SDAC form two general groups; one dedicated to basic seismological research, the other to the study of data management and processing techniques.

The second group of processing facilities, which is of most interest in the present context, includes two IBM 360/40s, a PDP-11 used to support a graphics terminal and a specialized Communications and Control Processor (CCP) which monitors and controls the flow of on-line data into the SDAC. These devices form the core of the Seismic Data Management System (SDMS) which is being developed to facilitate research using large data bases and to study the problems associated with the processing and analysis of digital data from a network of seismic stations.

All on-line data enter the SDMS through the CCP where portions of the data are forwarded to a Detection Processor (DP) which resides in one of the IBM 360/40s. The CCP forwards other data via the ARPANET to a large volume storage device, called the Datacomputer, in Cambridge, Massachusetts. Detections from the DP are passed to the second IBM 360/40 which serves as the Network Event Processor (NEP). In the NEP phase arrival queues are formed and detection associations and location estimates are made based on DP results and on detections entered from other sources such as the National Earthquake Information Service (NEIS) of the United States Geological Survey. The NEIS data are accessed via
telephone line from a computer file in Golden, Colorado. The major functions of the NEP may be monitored and controlled from a graphics terminal linked to the 360/40 by a PDP-11. This device allows a seismologist to monitor the detection queues, refine the automatic arrival time measurements, correct obviously erroneous associations and initiate epicentre location programmes. The results of the location programmes are displayed for review by the analyst who can continue to refine the measurements and relocate until he is satisfied with the event location and the associated station residuals. The result of this procedure is an event origin time and location entered into a list or bulletin. The location and source parameters in this event may be refined and added to through the NEP as later data arrive at the SDAC from Seismic Research Observatories (SROs) and overseas arrays. It is anticipated that the number and type of source parameters obtained will increase as more experience is gained through working with data from new sources such as the SROs. All preliminary and final results from the NEP are stored on the Datacomputer.

THE BLACKNEST DATA ANALYSIS CENTRE, BRIMPTON, READING, UNITED KINGDOM

Purpose

The task of the Blacknest Data Analysis Centre (BDAC) is research and development relevant to the seismic source verification programme of the United Kingdom Government.

Data Sources

The Centre is supported by a network of four short period seismometer arrays, three of which are operated by establishments in Australia, Canada and India; the fourth is located in the United Kingdom. Single long period and broad-band seismographs operate at each station. The magnetic tape analogue recordings from all these stations are retained in original for two years after which attempts are made by the United Kingdom Institute of Geological Sciences to preserve the principal earthquakes on edited library tape before the original is cleaned and recycled to the recording stations. Recordings of large explosions are edited and preserved at the BDAC.

Canada and India have developed and installed digital computer-based systems to monitor and continuously process their arrays. Similar systems have been developed for installation with digital recorders at the other arrays within the next year (1977/78). At the same time a digital system - the Array Network Data Analysis Computer (ANDAC) system - has been developed for handling, processing and storing all the incoming data at the BDAC.

These systems are designed to facilitate the verification research programme, but ultimately they may improve the contribution it may be possible for the United Kingdom to make towards seismological control of a test ban treaty.

In addition to these four principal data collection stations, signals are telemetered to BDAC via Post Office lines from an array of four broad-band systems (digitally recorded) and three short period elements sited within a radius of 50 km of BDAC.
A Post Office line carries eight channels of data to BDAC from the United Kingdom array. A telecopy link is also maintained between the station and the data centre. Time and amplitude data are recovered from the overseas arrays by commercial telex (Australia), radio and telex (India) and the ARPANET system (Canada via SDAC). The Canadian data include a preliminary location based on the best beam formed at the Yellowknife array. The system of data exchange that supports BDAC is essentially multilateral in the sense that each participating array centre gets within the same time frame the corresponding data from the other three arrays.

Procedures

As digital array processing systems are progressively installed, "best beam" information will be available from the other three arrays; in consequence more epicenters will be found among the onset time data. Meanwhile the procedures are, in summary, as follows:

(i) incoming numerical data are stored in fixed format, with facilities for immediate access and data file transfer, on the Rutherford High Energy Laboratory's computer (sited some 50 km north of BDAC) via remote terminals. These data can be accessed from the United Kingdom by terminals, or post office telephone service and from overseas by ARPANET

(ii) two epicenter programmes are employed; one accepts onset times from a number of stations, the second onset times from a seismometer array. If a source is located within an area of interest, both body and surface wave magnitude are estimated for that source

(iii) each week the data files are merged to produce a bulletin giving source parameters of recorded events. The bulletins are accessible for two weeks, the station files for one month; thereafter all data are archived. Hard copy is mailed to about 15 collaborators

(iv) should waveform data from overseas stations be required urgently, the magnetic tape is dispatched by air mail. Telexcopy systems have also been found suitable in certain cases.

Performance

To establish a reference level for this experiment a detailed analysis of its performance was made for 1975 using explosions as a measure. This was before Canadian (Yellowknife array) data became available on a prompt or fast response basis, and before the instrumentation of the Australian array (Warramunga) had been completed; these two stations are not included in the analysis.

The number of explosions reported during the year was 37 of which 26 were reported by one or more of the contributing stations. The smallest magnitude was reported by the Indian array \( m_b 4.4 \) from Sinkiang. The largest magnitude not reported by any station was \( m_b 4.8 \) from an explosion in Nevada.
Improvements must be expected from 1976 by the inclusion of the Australian and Canadian data. Further improvements await the installation of individual array processors. The time interval between the initiation of the seismic disturbance and verification of its nature is about a week and is unlikely to be shorter. In principle existing communication facilities permit a faster response, but experience has shown that without special manning arrangements (which are costly) a realistic response time with minimal interference to other domestic programmes is about a week. The United Kingdom array which is specially manned for the purpose at a cost of about $35,000 per year has a response time of one day. University operated research stations, whose assistants may extract the data as a favour, were observed to require 10 days until the opposite numbers on each end of the line became on first name terms, when the response time dropped to seven days and the service noticeably increased in reliability.

Good communications are desirable, but good will is of the essence of high performance.
APPENDIX V

Paper submitted to the Ad Hoc Group from the USSR expert on the identification of seismic events

1. Review of work undertaken in the USSR on the detection and identification of seismic events

A survey of the physical concepts of an underground explosion as a source of seismic disturbance of the environment is given in a paper by I. P. Pasechnik (1970) /1/.

This paper examines the kinetic and dynamic characteristics of body and surface seismic waves generated by nuclear explosions in different environments and also contains hodographs and graphs showing the dependence of the A/T ratios on the epicentral distance in the case of the most consistently traceable waves.

The paper establishes the differences in the dynamic characteristics of waves of the same types generated by different kinds of explosions and earthquakes, and in the dynamic relationships of waves of different classes. The criteria for identifying explosions are based on these differences. The basic criteria are the differences in the intensities of different classes of longitudinal and surface waves and in the shape of the wave trains of individual body and surface waves and of the whole recording, and the differences in the spectral composition of the oscillations in body waves. On the basis of a study of the spectra of waves generated by explosions, earthquakes and microseisms, ways of increasing the effective sensitivity of seismographic instruments are examined, and optimal pass bands are indicated. An estimate is made of the minimum levels of signals which can be picked up by single seismographs at stations with a low level of microseisms.

It is now generally recognized that the most effective way of differentiating between underground nuclear explosions and earthquakes is to use the so-called magnitude criterion. The difference between the mechanisms of explosion-type and earthquake-type sources lies in the fact that, though the P-wave intensity is the same, the surface Rayleigh wave intensity is substantially lower in the case of explosions. This difference may be conveniently expressed in the form of a magnitude discriminant of the type:

\[ \mu = M - am_B, \]

which does not depend on epicentral distance and magnitude.

Studies of this discriminant on the basis of recordings of underground explosions and earthquakes made at seismic stations in the USSR are described in a paper by I. P. Pasechnik et al. (1970) /2/. These studies show that identification of explosions by means of this discriminant is highly efficient.

Nevertheless, the magnitude criterion has some limitations in practical use, due to the impossibility at the present time of recording surface waves generated by low-yield explosions. Difficulties may also arise from the superimposition of
the recording of a surface wave on a recording of intensive long-period microseisms or of a surface wave from another source.

Accordingly, in the case of low-magnitude events, the role of discriminants describing the differences in short-period recordings of P-waves from explosions and earthquakes respectively becomes considerably more important.

The space-time properties of recordings of longitudinal waves from distant earthquakes (Δ ≥ 30°) are analysed in a paper by O. K. Kedrov (1971) [3].

This analysis has been used as a basis for selecting parameters characterizing the frequency composition of the P-waves (lgTₘₐₓ) and the shape of the whole wave train of the longitudinal waves (lgA₂, lgA₃, lgA₄, lgTₚ and lgT₀.₃), where

\[ A_1, A_2, A_3, A_4 \]

are the maximum amplitudes (in mm) in the following intervals of the P-wave recordings: 0-6 seconds, 6-12 seconds, 12-18 seconds and from 19 to the end of the recording for the longitudinal wave group;

\[ \tau_p \]

is the time (in seconds) during which the intensity of the oscillations increases from the moment of signal arrival to the maximum amplitude (Aₘₐₓ); and

\[ \tau₀.₃ \]

is the time (in seconds) during which the intensity of the graph declines to the level of 1/3 Aₘₐₓ.

The numerical values of these parameters form a random vector, each component of which has a logarithmically normal distribution. Some of the components have a correlation co-efficient of as much as 0.6-0.7. At the stations considered in this paper, these distributions may be regarded as homogeneous and constant in time. Differences between stations arise mainly in the mean values of the components and, to a lesser extent, of the dispersions.

An analysis of the dependence of the above parameters on magnitude, depth, epicentral distance, recording conditions at the station and the epicentral area has shown that the dominant factor is the effect of conditions at the station on these parameters; in absolute terms, this effect is considerable only on the parameters lgTₘₐₓ and lgT₀.₃.

The analysis undertaken in the paper leads to the conclusion that these parameters are suitable for the automatic identification of various types of seismic sources, such as deep-focus earthquakes and earthquakes with foci at lesser depths.

Research in the USSR on problems of determining the depth of the source of an earthquake by means of the dynamic parameters of the longitudinal wave recordings at individual stations have led to the establishment of a probabilistic method for solving this problem, and to the elaboration of an algorithm and programme for a computerized search for more informative parameters, and for using them to determine the depth of the focus.

The first of these two tasks, undertaken by V. F. Pisarenko and T. G. Reutian (1966) [4], consists of the formulation of a probability criterion by which an
event for which the vector $X = (X_1, \ldots, X_n)$ is observed can be related to one of two combinations represented by the probability densities $f_1 (X_1, \ldots, X_n)$ and $f_2 (X_1, \ldots, X_n)$.

The second work, by V. F. Pisarenko and A. A. Poplavsky (1971) [5], contains an algorithm for distinguishing between two images, on the assumption that the combination of the vectors of each image is subject to an unknown probability distribution.

This algorithm makes it possible to single out the most informative diagnostic parameters, especially for classifying earthquakes by depth. The results of evaluating the depth of the Kurile earthquakes were about 80 per cent accurate.

The problems of the relationship between the energy of an underground nuclear explosion and its magnitude were first examined by Y. V. Riznichenko (1960) [6]. At that time, this relationship was expressed in the form

$$m = 4.6 \pm 0.1 + (0.5 \pm 0.06) \log Y,$$

where $Y$ is the yield of the explosion in kilotons.

Problems of determining the seismic energy generated by explosions in the air, and by contact and underground explosions, are dealt with most fully in a monograph by S. Y. Kogan (1975) [7], who examines the spherical and axisymmetric sources of seismic oscillations and determines the energy which they radiate into seismic waves.

The author also sets forth a general method for calculating seismic energy at the focus. By this method, it is possible to establish a relationship between the seismic energy and the basic parameters of sources and the properties of the environment in which they operate.

Reliable determination of the magnitudes $m_b$ and $M_s$ of explosions and earthquakes is highly important in solving problems of detecting, locating and identifying explosions and earthquakes. This problem has been studied intensively in the USSR for many years. The stage now reached in determining the magnitude and classifying the energy of earthquakes is described in a collective work edited by N. V. Kondorskaya et al. (1974) [8].

This volume contains an analysis of the physical bases for determining magnitude; it discusses the nature and application of different magnitude scales; and it considers the methodological problems of determining magnitude on the basis of body and surface waves. It also contains a study of the spectral-time fields of seismic oscillations and their quantitative changes depending on the magnitude of the earthquake.

Problems of the optimal estimate of the magnitude of an earthquake or explosion source on the basis of weak body and surface waves as accorded by a network of stations are examined in a work by Y. N. Shtemenko and V. I. Tsibulsky (1976) [9].

The detection of weak longitudinal and surface waves caused by teleseismic events in conditions of intensive disturbances is an important factor in solving the problem of detecting and identifying types of seismic sources. This question
is examined in works by S. A. Kats et al. (1971-1973) /10, 11, 12/ and in papers by Y. M. Shtemenko et al. (1971-1974) /13, 14, 15/ from the standpoint of the theory of statistical solutions.

A paper by O. K. Kedrov et al. (1975) /16/ discusses the problem of detecting teleseismic P, SV and SH body waves and proposes the use of a polarization filter.

The methods of locating seismic sources, as developed and used by the Seismic Service of the USSR, are described in reference works /17, 18, 19/.

2. The choice of diagnostic parameters

The differences in the mechanism of generating seismic oscillations, in the case of underground nuclear explosions and earthquakes respectively, causes differences in the dynamic characteristics of seismic recordings. The basic differences are as follows:

- the shape of the envelope of the seismic recording is different in the case of explosions and earthquakes. (The relative intensity of the longitudinal, transverse and surface waves is different, as is the shape and duration of the wave trains in the individual wave groups);
- in the case of underground explosions, recordings of body waves and Lg surface waves are of a higher frequency than recordings of earthquakes;
- in the case of explosions, the first arrival of the longitudinal wave on recordings of displacements in all azimuths corresponds to the compression wave, while in the case of earthquakes some stations record the compression wave and some the rarefaction wave.

For the quantitative description of these differences in seismic recordings of explosions and earthquakes in a teleseismic range of distances of 3,000 km and more, the following parameters are used for recording seismic events:

1. The magnitude parameter: \( \mu = M_s - a m_b \), taking into account the different intensity of the generation of longitudinal and surface Rayleigh waves in the case of explosions and earthquakes respectively. Empirical evaluations of the relationship between \( M_s \) and \( m_b \) magnitudes obtained from seismic recordings of underground explosions and earthquakes gave the following equations for explosions and earthquakes respectively.

\[
M_s = (0.89 \pm 0.21)m_b - (0.55 \pm 0.12) \quad (\text{explosions})
\]

\[
M_s = (0.69 \pm 0.10)m_b + (1.16 \pm 0.06) \quad (\text{earthquakes})
\]

2. The frequency parameter: \( T_p \), where \( T_p \) is the period corresponding to the maximum amplitude in the longitudinal wave (cf. fig. I-IV).

3. Parameters characterizing the shape of the envelope of the recording of the longitudinal wave group:

\[
1g \left( \frac{A_2}{A_1} \right), 1g \left( \frac{A_3}{A_1} \right), 1g \left( \frac{A_4}{A_1} \right), 1g t^P, 1g t^P_{0.3}, 1g \left( \frac{D}{A_1} \right)
\]
Fig. I-IV. Illustration of a method of measuring the parameters of seismic recordings of longitudinal waves
where

\( A_1, A_2, A_3 \) and \( A_4 \) are the maximum oscillation amplitudes (in mm) at the following intervals in the recordings of the longitudinal waves: 0-6 seconds, 6-12 seconds, 12-18 seconds and 19 seconds to the end of the fifth minute of the recording of the signal:

\( t^p_h \) is the time (in seconds) of the increase in the intensity of the P-wave recording up to \( A_{\text{max}} \);

\( D \) is the duration (in minutes) of the recording of the longitudinal waves from the time of signal arrival until the background level is reached.

All the above parameters are measured on the vertical component of a short-period seismograph (SKM-Z).

In the USSR, an estimate has also been made of the efficiency of the spectral identification criterion. To this end, spectral coefficients of the \( K_{ij} \) type were calculated for the P-wave spectra:

\[
K_{ij} = \frac{1}{i j} \frac{A_i}{A_j}
\]

where \( i \) represents the current frequencies of the spectral components and \( j \) a fixed frequency close to the frequency of the maximum amplitude of the spectrum.

These parameters have been analysed statistically by sampling from 50 underground explosions and about 500 earthquakes recorded on the USSR seismic network. The results of the analysis are as follows:

1. In the case of explosions, the period of maximum amplitude of the longitudinal wave depends only slightly on the magnitude:

\[
T_p = (0.08 \pm 0.01) M_B - (0.41 \pm 0.02)
\]

In the case of earthquakes, this dependence, measured on broad-band instruments is greater:

\[
T_p = (0.15 \pm 0.06) M_S - (0.26 \pm 0.03).
\]

2. In the case of explosions and earthquakes alike, the periods of the longitudinal wave increase only slightly with an increase in epicentral distance, so that this dependence can be ignored.

3. The shape of the envelope of the recording of teleseismic longitudinal waves in the case of explosions and earthquakes depends only slightly on magnitude and practically not at all on epicentral distance.

4. The nature of the recording of the longitudinal waves in the case of earthquakes depends on the depth of the focus. Where \( h \geq 80 \text{ km} \), the values of the parameters \( \frac{A_2}{A_1}, \frac{A_3}{A_1} \), \( t^p_h \) and \( T_p \) are on the average lower than for surface earthquakes.
5. The factors which have the greatest effect on the dynamic parameters of a seismic recording of longitudinal waves on narrow-band instruments are the seismological conditions in the vicinity of the recording station; in such cases, the effect of the epicentral area is merely secondary.

6. Correlation links between the parameters are not significant, in the case of recordings, either of explosions or of earthquakes.

These conclusions show that the selected parameters are informative in the task of differentiating between seismic recordings of explosions and earthquakes.

3. A probability criterion for differentiating between seismic recordings of explosions and earthquakes

The differentiation of recordings of explosions from recordings of earthquakes is a typical problem of recognition. The process of recognition includes the search for diagnostic criteria and a statistical evaluation of their efficiency in dividing the events under study into classes.

Since, in accordance with the criteria selected, explosions and earthquakes are intersecting classes, virtually none of the above-mentioned parameters is adequate for making a complete division between them. Accordingly, a statistical probability criterion is introduced into the task of differentiating between explosions and earthquakes. It is essential to give each identification parameter a probability significance and, on the basis of the aggregate of these probabilities to calculate the total probability \( P_0 \) that a seismic signal being studied belongs to the category of explosions. This classification method is examined in detail in a paper by V. F. Pisarenko and T. G. Rautian in Computerized Seismology, No. 2, 1966.

The total probability \( P_0 \) of an explosion is calculated by the Bayes formula for obtaining the product of partial probabilities, as follows:

\[
P_0 = \frac{\prod_{i=1}^{n} P_i}{\sum_{i=1}^{n} P_i + \prod_{i=1}^{n} (1 - P_i)}
\]

where \( P_i \) is the partial probability for parameter \( i \) (\( i = 1, 2 \ldots, n \)).

An event is assigned to one or the other class on the basis of a selected threshold value for the total probability, which will correspond to specific values for the probability of error in classifying \( \alpha \) and \( \beta \) (\( \alpha \) being a miss and \( \beta \) a false alarm).

4. The efficiency of identifying explosions at a particular station

The efficiency of identifying recordings of explosions and earthquakes at a particular station has been assessed at a number of stations in the USSR using the above-mentioned probability criterion without the magnitude criterion. This assessment has shown that the efficiency of identifying recordings of earthquakes \( (I - \beta) \) varies from station to station between 70 and 90 per cent, with \( \alpha \) (explosions missed) = 5 per cent.

-203-
An analysis of the efficiency of the magnitude parameter $\mu$ shows that it permits identification of 85 per cent of earthquake recordings at a particular station, with $\alpha = 5$ per cent.

The efficiency of differentiation without the magnitude parameter has been assessed with a view to demonstrating the possibility of identifying recordings of explosions in the absence of recordings of surface waves, which is usually the case with low-yield explosions.

5. Group criteria and the efficiency of differentiating between recordings of explosions and earthquakes using a network of stations

An analysis of seismic recordings of explosions and earthquakes made by a network of 10 stations in the USSR made it possible to establish the following group identification criteria:

The probability criterion $P$. In cases where a seismic event has been recorded at several stations, the aggregate probability $P$, determined on the basis of the values of the total probabilities $P_o$ of the recordings of the event at all stations, may be used for a probability assessment of the question whether the event was an explosion. For constructing the criterion $P$, the methods used are the same as those for the criterion $P_o$.

The focus depth criterion. The depth of the focus of a remote earthquake is determined by the difference in the arrivals of the $pP-P$ and $sP-P$ waves. This criterion is reliable in detecting earthquakes with a focus depth below the bottom of the earth's crust ($M$ boundary). However, studies in recent years have shown that, in a number of cases, analysis of the spectra and capstrums of the $P$ waves of the signal makes it possible to distinguish the $pP$ phase for near-surface focus earthquakes and for explosions.

Criterion of the sign of the first arrivals in the longitudinal $P$ wave. The sign criterion (direction of the first arrival on the recording) is based on the difference in source mechanism between an explosion and an earthquake. In the case of an explosion, the symmetrical radiation of the seismic energy is such that the direct longitudinal wave is recorded as a compression wave in all azimuths. The nature of the disturbances at the foci of earthquakes is such that compression waves are radiated in some azimuths and rarefaction waves in others. For the successful use of this criterion, high signal/noise ratios are required. Its efficiency will increase as recording methods are improved.

Dispersion of the $\log t^D_h$ parameter at stations. Variations in the shape of the recording at various stations in different azimuths are more marked in the case of earthquakes than for explosions. These variations are due to the difference in the types of sources.

An analysis of the dispersion of station identification parameters at a network of stations showed that the $\log t^D_h$ parameter is very efficient in the identification of earthquakes with a high "explosion" probability in accordance with the probability criterion $P$, and with a zero probability of error in missing explosions. Thus, it is advisable to use the dispersion or standard deviation
of the $\lg t^P$ parameter, i.e. $\sigma \lg t^P$, as a group criterion. Using this parameter, it is possible to identify 70 per cent of the earthquakes which are still similar to an explosion after application of the $P$ criterion, without failing to identify any explosions.

The efficiency of differentiation between seismic recordings of underground explosions and earthquakes, using station and group criteria, was verified on the basis of material obtained from 100 remote ($\Delta \geq 30^\circ$) earthquakes with epicentres in various seismologically active areas of the world, as recorded on 5 $\leq k \leq 10$ seismic stations in the USSR.

The analysis showed that all earthquakes can be correctly identified, and all explosions identified as such, when all the station and group criteria described above are taken into account.

The physical criteria described in this section for identifying explosions and earthquakes fully coincide with the physical criteria used by seismologists in various countries in classifying seismic recordings of explosions and earthquakes. There are some differences in the nature of certain diagnostic parameters describing these physical criteria, but it is quite obvious that it is possible to propose a large number of diagnostic parameters which may be different but will have approximately the same identification efficiency.

In this connexion, it is advisable to use the probability method for identifying seismic recordings of explosions and earthquakes, irrespective of the diagnostic parameters from which the probability criterion is constructed. It may be pointed out, for example, that the use of the "complexity" diagnostic parameter in the probability form makes it possible to identify 50 per cent of the earthquakes recorded, with only a 5 per cent failure to identify explosions, at a single station. This is close to the results obtained using parameters of the type $\lg (A_2/A_1)$, $\lg (A_3/A_1)$, $\lg (A_h/A_1)$, $\lg (D_0/A_1)$, $\lg t^P_H$ and $\lg \tau^P_{0.3}$, but less than the identification ratio obtained by their aggregate use on a probability basis.

One important aspect in the formulation of the probability criterion is the selection of the optimum set of identification parameters. In recent years, programmes for the computerized selection of the optimum set of the most informative parameters, in order to determine the depth of crust earthquakes from a given series of parameters, as well as programmes for the probability classification of the depth of the source of crust earthquakes, have been elaborated and tested in the USSR.

The criteria described above are equally suitable for use both with analogue and digital recordings and for the automatic processing of recordings.
References


10. Kats, S. A., Starodubrovskaya, S. P., Evaluations of the parameters of seismic waves distorted by interferences with unknown statistical characteristics. (From the work entitled "Interpretation and Detection of Seismic Waves in Heterogeneous Environments", "Nauka", Moscow, 1971.)


-206-


BULGARIA, CZECHOSLOVAKIA, GERMAN DEMOCRATIC REPUBLIC, HUNGARY, MONGOLIA, POLAND, ROMANIA AND UNION OF SOVIET SOCIALIST REPUBLICS

Draft convention on the prohibition of the production, stockpiling, deployment and use of nuclear neutron weapons

The States Parties to this Convention,

Expressing the profound interest of States and peoples in preventing the use of the achievements of modern science and technology for the development and production of new types of weapons of mass destruction,

Desiring to contribute to the halting of the arms race, particularly in the field of means of mass destruction,

Realizing the danger which nuclear neutron weapons present to the peace and security of peoples,

Have agreed as follows:

Article I

Each State Party to this Convention undertakes not to produce, stockpile, deploy anywhere or use nuclear neutron weapons.

Article II

1. Control over compliance with this Convention shall be exercised by the States Parties, using the national technical means of verification which are at their disposal, in a manner conforming to the universally recognized rules of international law.

2. The States Parties to this Convention undertake to consult one another and to co-operate in solving any problems which may arise in relation to the objectives of, or in the application of the provisions of, the Convention. Consultations and co-operation pursuant to this article may also be undertaken through appropriate international procedures within the framework of the United Nations and in accordance with its Charter.

3. Any State Party to this Convention which claims that any other State Party may be acting in breach of the obligations assumed under this Convention may lodge a complaint with the Security Council of the United Nations.
4. Each State Party to this Convention undertakes to co-operate in carrying out any investigation which the Security Council may initiate, in accordance with the provisions of the Charter of the United Nations, on the basis of the complaint received by the Council. The Security Council shall inform the States Parties to the Convention of the results of the investigation.

**Article III**

This Convention shall be of unlimited duration.

**Article IV**

This Convention shall be open to all States for signature.

**Article V**

1. This Convention shall be subject to ratification by signatory States. Instruments of ratification shall be deposited with the Secretary-General of the United Nations who is hereby designated as the Depositary.

2. This Convention shall enter into force upon the deposit of instruments of ratification by ... Governments.

**Article VI**

1. This Convention, of which the Arabic, Chinese, English, French, Russian, and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

2. This Convention shall be registered by the Depositary in accordance with Article 102 of the Charter of the United Nations.
MEXICO

Some fundamental principles and norms for inclusion in the declaration on disarmament envisaged in the draft agenda of the special session of the General Assembly devoted to disarmament, approved by the Preparatory Committee on 18 May 1977 (A/AC.187/56)

Outline of a draft final document of the special session of the General Assembly devoted to disarmament (A/AC.187/89 and Add.1)

For the text of documents A/AC.187/89 and Add.1, see Official Records of the General Assembly, Tenth Special Session, Supplement No. 1, vol. V.
Terms of reference for the continued work of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events

Recognizing the valuable and important work carried out by the Ad Hoc Group and presented to the CCD in its report of 14 March, taking note of the suggestion by the Ad Hoc Group to conduct additional work and also of a similar suggestion by the Japanese delegation (CCD/PV.733) CCD decides that the Ad Hoc Group as constituted under the previous mandate continues its work by studying practical aspects of the implementation of international co-operative measures.

The continued work of the Ad Hoc Group should begin with a planning and preparatory phase where the following items have to be further studied and specified.

- Data to be routinely produced at participating stations (level 1 data);
- Format for data transmission on WMO communication network;
- Procedures to be used for data analysis at data centres;
- Format and procedures for the exchange of wave form data (level II data);
- Detailed programme and time scale for practical experiments.

The practical experiments to be conducted would include the following elements:

- obtain practical experience of international co-operative measures and thereby shorten the lead time necessary for the implementation of a procedure for international exchange of seismic data should this later be decided;
- test the over-all functioning of a seismological data exchange system consisting of a global network of seismological stations, a telecommunication system and temporary seismological data centres;
- determine experimentally the operating efficiency and possible deficiencies of such a data exchange system, including its capabilities in the southern hemisphere.

The technical arrangements studied during the practical experiment should not prejudice the final arrangements of a monitoring system. The evaluation of
the experiment should be purely scientific and the group should not assess the adequacy of the system for verifying a comprehensive test ban.

To facilitate a rapid solution of these technical questions the work could be prepared in informal technical working parties established by the Ad Hoc Group and open to all members of the Ad Hoc Group. These working parties could meet at places where appropriate technical facilities for their work exist and at times the working groups find appropriate for a rapid conclusion of their work. The matters prepared in such informal technical working groups should be discussed and decided on at plenary meetings with the Ad Hoc Group.

Membership in the Ad Hoc Group will be open to scientific experts nominated by any CCD member State. In order to enable the Group to draw on expertise of other States, membership in the Ad Hoc Group will also be kept open to scientific experts nominated by States Members of the United Nations that are not represented in the CCD, upon invitation of the CCD. By nominating experts to participate in the Group, States do not commit themselves to the adequacy of the international co-operative measures studied. The facilities and data needed for the practical experiment would be contributed by participating countries on a voluntary basis and no international funding is foreseen. The costs of temporary data centres will be carried by the countries in which they are established.

The Ad Hoc Group should work as quickly as possible and the result of the initial planning and preparatory phase should be reported to the CCD in the beginning of the spring session 1979. The practical experiment should be gradually initiated as soon as necessary technical arrangements have been made and aim at establishing a temporary data exchange at the end of this year.

The Ad Hoc Group will under its new mandate hold its next meeting during the week beginning ...
Working paper on organization and procedures of the Conference of the Committee on Disarmament submitted by the members of the Group of 15

The Group of 15, which has for some time been concerned with the question of organization and procedures of the Conference of the Committee on Disarmament, is convinced that the CCD should be the subject of such changes as to increase its effectiveness and to create the necessary conditions for the participation in its work of all nuclear-weapon States.

To this effect, the Group believes – without prejudice to any decision which the first special session of the United Nations General Assembly devoted to disarmament may adopt – that the following modifications deserve the highest priority:

1. Strengthening of the existing link between the General Assembly and the CCD. For this purpose it is necessary that:

   (a) All Member States of the United Nations may submit directly proposals on measures of disarmament that are the subject of negotiations in the CCD and participate in its proceedings as well as in those of the working bodies in which such a proposal or proposals are examined;

   (b) The Special Representative of the Secretary-General and the Centre for Disarmament of the United Nations should be assigned an appropriate enhanced role in the CCD.

2. Replacement of the system of co-chairmanship by a system to be agreed upon.

Among the various suggestions made in this respect, it is worthwhile recalling for illustrative purposes the following:

   (a) The CCD should be presided by a chairman on the basis of monthly rotation (CCD/550);

   (b) Monthly rotation between all non-nuclear-weapon States members of the CCD (CCD/PV.762 and CCD/561);

   (c) The present co-chairmanship institution should be replaced by a bureau of four members, consisting of one chairman and three vice-chairmen. Two members of the bureau should be selected from the States belonging to the military blocs and the other from the group of neutral and non-aligned States in the CCD. The chairmanship should rotate in alphabetical order on a monthly or sessional basis between all members of the CCD (CCD/554).
3. Adoption by the CCD of its own rules of procedure.

4. Examination of relevant procedures to improve the effectiveness of the CCD including inter alia the establishment of a standing sub-committee of the whole as envisaged in document CCD/530.

5. The plenary meetings of the CCD should be public.
Draft decision of the Conference of the Committee on Disarmament on
the establishment of an ad hoc group of qualified governmental
experts to consider the question of possible areas of the development
of new types and systems of weapons of mass destruction

The Conference of the Committee on Disarmament, taking into account the fact
that at its thirty-second session the United Nations General Assembly urged States
to refrain from developing new types of weapons of mass destruction and new systems
of such weapons based on new scientific principles, and requested the Conference of
the Committee on Disarmament to continue negotiations, with the assistance of
qualified governmental experts, aimed at working out the text of an agreement on
the prohibition of the development and manufacture of new types of weapons of mass
destruction and new systems of such weapons, decides to establish under its auspices
an ad hoc group of qualified governmental experts to consider the question of
possible areas of development of new types and systems of weapons of mass
destruction to be included in the initial list of the types of such weapons to be
prohibited under a comprehensive agreement (CCD/511/Rev.1).

Scientific experts appointed by any State member of the Conference of the
Committee on Disarmament may take part in the work of the Ad Hoc Group. To enable
the Group to draw upon the knowledge and experience of other States, scientific
experts appointed by States Members of the United Nations not represented in the
Conference of the Committee on Disarmament may also take part in the Ad Hoc Group
on the invitation of the Conference of the Committee on Disarmament.

The Ad Hoc Group shall hold its first meeting in the week beginning
7 August 1978. The Conference of the Committee on Disarmament suggests that the
Group should present its progress report to the Conference before the end of the
1978 summer session.

The Conference of the Committee on Disarmament decides that the Group shall
elect its chairman. It further decides that the Group should aim at consensus in
its reports, and that in cases where consensus cannot be reached, each expert shall
be entitled to state his own point of view in the reports.

The Group should conduct its work on an informal basis preparing unofficial
working papers and records where needed. The report to the Conference of the
Committee on Disarmament shall be prepared as an official document.

The Conference of the Committee on Disarmament requests the Secretariat to
arrange for the Group to be given the necessary assistance and services.
NETHERLANDS

Study on the establishment of an international disarmament agency

Proposal

In the opinion of the Netherlands, a number of recent developments in the field of disarmament as well as the international situation warrant a reconsideration of the idea of an international disarmament agency. With possibly more and more complicated multilateral disarmament treaties, a need seems to arise for a permanent organization to streamline the consultations and the implementation measures.

Therefore, the Netherlands proposes that an International Disarmament Agency (IDA) be established.

To that effect, the Netherlands suggests that in the Final Document of the special session of the General Assembly of the United Nations devoted to disarmament an invitation should be included to seek the views of all Member States on such an international disarmament agency.

Introduction

In the past, several suggestions and proposals have been made to establish a standing disarmament organ or an international disarmament agency, e.g., in 1973 both Sweden 1/ and the Netherlands 2/ expressed detailed views on this subject in the Conference of the Committee on Disarmament. The standing disarmament organ, as proposed by the Netherlands would firstly be entrusted with the verification of a treaty banning chemical weapons. However, it was envisaged from the beginning that such an organ could take upon itself other tasks, such as the verification of other arms control and disarmament treaties as well as the organization of review conferences provided for in such treaties. In the absence of prospects, at that time, for substantial multilateral disarmament agreements as well as for other reasons, the ideas put forward by Sweden and the Netherlands were not pursued to any further degree. At present, the international situation seems to be more responsive to a reconsideration of these ideas. Indeed, several countries suggested the establishment of such an organ during the preparations of the special session of the General Assembly of the United Nations devoted to disarmament or made proposals which are relevant for a discussion on this subject.

Possible functions of an international disarmament agency

In this working paper an international disarmament agency is envisaged as the operational framework for the implementation of international arms control and disarmament treaties, with functions mainly in the field of verification. In addition, it is thought that such an agency could be instrumental to the preparation and organization of review conferences already provided for in several disarmament treaties and could serve as a clearing house for information on disarmament.

The idea takes into account the following considerations and ongoing developments:

(a) A convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction seems within reach in the foreseeable future. It seems probable that such a convention will provide for rather extensive consultations between parties, in particular technical discussions on the precise agents to be banned or restricted and on implementation measures. The treaty would probably provide for rather extensive notification and verification procedures. Besides regular political and technical discussions between parties, a permanent staff seems necessary for the implementation of the convention.

(b) A treaty banning nuclear tests seems also within reach. An international seismic system will in all probability be established to exchange and process seismic data. A consultative organ of parties to the treaty seems necessary, both with respect to solving technical and organizational problems of the seismic system - including the administration of international seismic data centres - as to discuss other matters with respect to the implementation of the treaty, such as working out procedures for on-site inspection and the actual carrying out of such inspections.

(c) Also for other existing and future multilateral disarmament agreements there may be a need for consultations between interested countries, in particular by the parties to these treaties, as well as for implementation measures. With more and more complicated multilateral disarmament treaties, a need seems to arise for a permanent organization to streamline the consultations and the implementation measures. Otherwise, a substantial number of consultative commissions, some of them with permanent staffs, seems required, all perhaps differently organized.

(d) The proposal by France to establish an international agency for satellite observation commands particular attention. The Netherlands shares the view of France that the present situation that information which can be obtained by satellite is in the hands of only a few countries is undesirable, in particular in cases where such information is a prerequisite for the verification of multilateral treaties. The Netherlands recognizes, however, the practical problems to establish an international satellite agency. It is also of the view that observation by satellite cannot provide all information necessary to verify present and future arms control treaties. For example, satellites cannot provide most or all verification functions with respect to a ban on underground nuclear tests or chemical disarmament. It would therefore be necessary not to concentrate on satellite observation only but to combine different verification tasks and methods in one agency, which would be the international disarmament agency.
(e) Several disarmament treaties now provide for more or less regular review conferences. An international disarmament agency as proposed could provide the operational framework for the organisation of review conferences. Preparations and proceedings of review conferences could thus be streamlined. The existence of permanent consultative machinery could also facilitate the organization of review conferences, thereby rendering them more efficient.

(f) Relevant information with respect to the implementation of arms control and disarmament agreements could be combined in one organization. Data on various disarmament measures, such as for instance stockpile-destruction, seismic data, results of inspections and fact-finding missions could be stored with one organization which would act as a clearing house for information on all implementation efforts in the field of disarmament.

A possible approach

In the view of the Netherlands the international disarmament organization could be set up initially for the implementation of a particular disarmament treaty, and could then gradually be given more functions dependent of emerging needs and taking into account experience gained. The existence of a permanent disarmament organization would make it possible during negotiations on other disarmament measures to allot certain functions to the organization and thus avoid creating new bodies. The agency would, of course, only perform functions which are specifically given to it by the parties to particular arms control and disarmament treaties. A link with the United Nations seems also desirable.

Structure of the organization

The agency could be constructed along the familiar pattern of many international organizations, such as a plenary conference, a board and a secretariat. Membership of the conference would pose no problem if the agency would function in the context of one arms control or disarmament treaty only, since the members of the conference would be the parties to the treaty. As a nucleus for a disarmament organization having more functions, the conference would have to be open-ended. Rights and duties of individual members would then have to be determined by their adherence to the treaties under consideration.

While the conference, as a rule, would only meet at certain intervals, the board would have to be so organized as to be able to function continuously. Members of the board would be elected by the conference. Its main functions could be envisaged as providing practical guidance to the work of the agency on the basis of guidelines to be given by the conference.

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.

Summary and conclusion

Above some preliminary views are given by the Netherlands. It is recognized, of course, that careful study and consideration is necessary before the international community can decide on the establishment of a new international organ. Also, results of ongoing disarmament negotiations, in particular with
respect to chemical weapons and the comprehensive test ban, would have an influence on the subject. The Netherlands proposes therefore, a number of steps which could ultimately lead to the establishment of an international disarmament agency if and when the world community considers it opportune.

As a first step, the Secretary-General of the United Nations would seek the view of Governments on this question, in particular on the functions to be given to an international disarmament agency, its structure and its link with the United Nations. Answers could be expected by Governments before the thirty-fourth session of the General Assembly and the Secretary-General could make an analysis of the different ideas and opinions expressed by Member States.

A next step could be that the General Assembly, if the answers warrant such a step, decides to establish a committee which would further negotiate on the structure and functions of a possible disarmament organization. The last step could be the actual establishment of such an organization, for example at a second special session of the General Assembly devoted to disarmament.

Consequently, the Netherlands proposes the following wording to be included in the Final Document of the special session:

"The Secretary-General is requested to seek the views of Member States with respect to the functions and organization of a possible international disarmament agency and to submit these views and an analysis thereof to the thirty-fourth session of the General Assembly."
Compilation of the documents and proposals submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament which are relevant to the consideration of the comprehensive programme of disarmament

Introductory note by the Secretariat

In the decision adopted by the CCD at its informal meeting on 2 March 1978 establishing an Ad Hoc Working Group of the Committee to discuss and elaborate a draft comprehensive programme of disarmament, the Committee requested the Secretariat "to circulate as CCD documents those documents and proposals on the comprehensive programme of disarmament which may have been or may be submitted to the Preparatory Committee of the Special Session of the United Nations General Assembly Devoted to Disarmament".

The present document is a compilation of the documents and proposals submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament up to 31 March 1978, which are relevant to the consideration of a comprehensive programme of disarmament.
List of documents:


2. Working paper submitted by Mexico on some fundamental principles and norms for inclusion in the "Declaration on Disarmament" envisaged in the draft agenda of the special session of the General Assembly devoted to disarmament, approved by the Preparatory Committee on 18 May 1977 (A/AC.187/56). Also submitted to the CCD by Mexico (CCD/550).

3. Working paper submitted by Mauritius containing some views on the content of the final document(s) of the Special Session of the General Assembly Devoted to Disarmament (A/AC.187/60).


7. Working paper submitted by Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Mongolia, Poland and the Union of Soviet Socialist Republics containing some basic provisions of the declaration on disarmament (A/AC.187/81).


10. Working paper submitted by Australia, Belgium, Canada, Denmark, Germany, Federal Republic of Italy, Japan, Netherlands, Norway, Turkey and United Kingdom of Great Britain and Northern Ireland containing a draft declaration on disarmament (A/AC.187/37).


14. Working paper submitted by Venezuela on elements to be included in the Preamble, the Declaration and the Programme of Action (A/AC.187/94).

15. Working paper submitted by Sweden on elements for inclusion in the programme of action and in the documents relating to the machinery for disarmament negotiations (A/AC.187/95). Also submitted to the CCD by Sweden (CCD/554).


22. Working paper submitted by Italy on international mechanisms for disarmament (A/AC.187/110). Also submitted by Italy to the CCD (CCD/568).

Tabulation of working papers and proposals on a comprehensive programme of disarmament

DOCUMENT CCD/567

/For the text, see Official Records of the General Assembly, Tenth Special Session, Supplement 2A, annex 1./

DOCUMENT CCD/567/Add.1

In the introductory note by the Secretariat, after No. 22 add:


In section VII. Machinery and Procedures for Disarmament Negotiations, under the subheading "Netherlands" add the symbol CCD/565, 30 March 1978, and text reading as follows:

Proposal

In the opinion of the Netherlands, a number of recent developments in the field of disarmament as well as the international situation warrant a reconsideration of the idea of an international disarmament agency. With possibly more and more complicated multilateral disarmament treaties, a need seems to arise for a permanent organization to streamline the consultations and the implementation measures.

Therefore, the Netherlands proposes that an International Disarmament Agency (IDA) be established.

To that effect, the Netherlands suggests that in the Final Document of the special session of the General Assembly of the United Nations devoted to disarmament an invitation should be included to seek the views of all Member States on such an international disarmament agency.
Introduction

In the past, several suggestions and proposals have been made to establish a standing disarmament organ or an international disarmament agency, e.g. in 1973 both Sweden 1/ and the Netherlands 2/ expressed detailed views on this subject in the Conference of the Committee on Disarmament. The standing disarmament organ, as proposed by the Netherlands would firstly be entrusted with the verification of a treaty banning chemical weapons. However, it was envisaged from the beginning that such an organ could take upon itself other tasks, such as the verification of other arms control and disarmament treaties as well as the organization of review conferences provided for in such treaties. In the absence of prospects, at that time, for substantial multilateral disarmament agreements as well as for other reasons, the ideas put forward by Sweden and the Netherlands were not pursued to any further degree. At present, the international situation seems to be more responsive to a reconsideration of these ideas. Indeed, several countries suggested the establishment of such an organ during the preparations of the special session of the General Assembly of the United Nations devoted to disarmament or made proposals which are relevant for a discussion on this subject.

Possible functions of an international disarmament agency

In this working paper an international disarmament agency is envisaged as the operational framework for the implementation of international arms control and disarmament treaties, with functions mainly in the field of verification. In addition, it is thought that such an agency could be instrumental to the preparation and organization of review conferences already provided for in several disarmament treaties and could serve as a clearing house for information on disarmament.

The idea takes into account the following considerations and ongoing developments:

(a) A convention on the prohibition of the development, production and stockpiling of chemical weapons and on their destruction seems within reach in the foreseeable future. It seems probable that such a convention will provide for rather extensive consultations between parties, in particular technical discussions on the precise agents to be banned or restricted and on implementation measures. The treaty would probably provide for rather extensive notification and verification procedures. Besides regular political and technical discussions between parties, a permanent staff seems necessary for the implementation of the convention.

(b) A treaty banning nuclear tests seems also within reach. An international seismic system will in all probability be established to exchange and process seismic data. A consultative organ of parties to the treaty seems necessary, both with respect to solving technical and organizational problems.

of the seismic system - including the administration of international seismic
data centra - as to discuss other matters with respect to the implementation
of the treaty, such as working out procedures for on-site inspection and the
actual carrying out of such inspections.

(c) Also for other existing and future multilateral disarmament
agreements there may be a need for consultations between interested countries,
in particular by the parties to these treaties, as well as for implementation
measures. With more and more complicated multilateral disarmament treaties,
a need seems to arise for a permanent organization to streamline the
consultations and the implementation measures. Otherwise, a substantial number
of consultative commissions, some of them with permanent staffs, seems
required, all perhaps differently organized.

(d) The proposal by France to establish an international agency for
satellite observation commands particular attention. The Netherlands shares
the view of France that the present situation that information which can be
obtained by satellite is in the hands of only a few countries is undesirable,
in particular in cases where such information is a prerequisite for the
verification of multilateral treaties. The Netherlands recognizes, however,
the practical problems to establish an international satellite agency. It is
also of the view that observation by satellite cannot provide all information
necessary to verify present and future arms control treaties. For example,
satellites cannot provide most or all verification functions with respect to
a ban on underground nuclear tests or chemical disarmament. It would therefore
be necessary not to concentrate on satellite observation only but to combine
different verification tasks and methods in one agency, which would be the
international disarmament agency.

(e) Several disarmament treaties now provide for more or less regular
review conferences. An international disarmament agency as proposed could
provide the operational framework for the organization of review conferences.
Preparations and proceedings of review conferences could thus be streamlined.
The existence of permanent consultative machinery could also facilitate the
organization of review conferences, thereby rendering them more efficient.

(f) Relevant information with respect to the implementation of arms
control and disarmament agreements could be combined in one organization. Data
on various disarmament measures, such as for instance stockpile-destruction,
seismic data, results of inspections and fact-finding missions could be stored
with one organization which would act as a clearing house for information on
all implementation efforts in the field of disarmament.

A possible approach

In the view of the Netherlands the international disarmament organization
could be set up initially for the implementation of a particular disarmament
treaty, and could then gradually be given more functions dependent on emerging
needs and taking into account experience gained. The existence of a permanent
disarmament organization would make it possible during negotiations on other
disarmament measures to allot certain functions to the organization and thus
avoid creating new bodies. The agency would, of course, only perform functions
which are specifically given to it by the parties to particular arms control and disarmament treaties. A link with the United Nations seems also desirable.

Structure of the organization

The agency could be constructed along the familiar pattern of many international organizations, such as a plenary conference, a board and a secretariat. Membership of the conference would pose no problem if the agency would function in the context of one arms control or disarmament treaty only, since the members of the conference would be the parties to the treaty. As a nucleus for a disarmament organization having more functions, the conference would have to be open-ended. Rights and duties of individual members would then have to be determined by their adherence to the treaties under consideration.

While the conference, as a rule, would only meet at certain intervals, the board would have to be so organized as to be able to function continuously. Members of the board would be elected by the conference. Its main functions could be envisaged as providing practical guidance to the work of the agency on the basis of guidelines to be given by the conference.

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.

Summary and conclusion

Above some preliminary views are given by the Netherlands. It is recognized, of course, that careful study and consideration is necessary before the international community can decide on the establishment of a new international organ. Also, results of ongoing disarmament negotiations, in particular with respect to chemical weapons and the comprehensive test ban, would have an influence on the subject. The Netherlands proposes, therefore, a number of steps which could ultimately lead to the establishment of an international disarmament agency if and when the world community considers it opportune.

As a first step, the Secretary-General of the United Nations would seek the view of Governments on this question, in particular on the functions to be given to an international disarmament agency, its structure and its link with the United Nations. Answers could be expected by Governments before the thirty-fourth session of the General Assembly and the Secretary-General could make an analysis of the different ideas and opinions expressed by Member States.

A next step could be that the General Assembly, if the answers warrant such a step, decides to establish a committee which would further negotiate on the structure and functions of a possible disarmament organization. The last step could be the actual establishment of such an organization, for example at a second special session of the General Assembly devoted to disarmament.

Consequently, the Netherlands proposes the following wording to be included in the Final Document of the special session:
The Secretary-General is requested to seek the views of Member States with respect to the functions and organization of a possible international disarmament agency and to submit these views and an analysis thereof to the thirty-fourth session of the General Assembly.

In the same section, under the column bearing the name "Italy" add the symbol CCD/568, 24 April 1978 and text reading as follows:

The special session of the General Assembly devoted to disarmament provides an important opportunity to consider and to evaluate existing multilateral mechanisms and to make suggestions and recommendations for their improvement.

In a review of the adequacy of international disarmament machinery, the following elements should be considered:

1. the vital interest of all nations in the outcome of disarmament negotiations and the need for a more conscious and direct participation of all States in disarmament endeavours;

2. the special responsibility incumbent upon nuclear-weapon Powers and other militarily significant States and their primary role in effective progress toward disarmament, particularly nuclear disarmament;

3. the desirability of a better co-ordination among bilateral, regional and multilateral efforts, with a view to over-all achievements toward the ultimate goal of general and complete disarmament;

4. the necessity for a parallel strengthening of the international security system and of the establishment of adequate verification mechanisms in order to assure the effective implementation and the strict fulfilment of agreed disarmament measures.

Against this background, Italy believes that the special session should focus its attention on the following main components of the international disarmament machinery:

(a) United Nations General Assembly

The General Assembly provides the natural and most appropriate forum for the consideration, on a universal basis and with the participation of all Member States, of the principles governing disarmament and the regulation of armaments.

In view of rationalizing debates and rendering decision-making more effective, all disarmament items should be allocated to the First Committee, which should mainly concentrate its activity on disarmament and international security matters.

To this end, any other suitable revision of the procedures should be readily envisaged, bearing in mind the recommendations of the Ad Hoc Committee on the Review of the Role of the United Nations in the Field of Disarmament.

Ad hoc committees of the General Assembly could be set up to deal with issues deserving special consideration.

-228-
While the General Assembly should remain the regular forum for the annual review of disarmament problems, it might be appropriate to convene, in due course, a further special session for the specific purpose of:

(a) appraising the implementation of the Programme of Action;

(b) identifying guidelines for the next sequence of negotiations;

(c) considering and possibly adopting a comprehensive programme of disarmament.

(b) Security Council

Consideration should be given to the specific contribution which the Security Council could make to disarmament progress.

To this effect, it is suggested that the Security Council should review the implementation of its responsibilities in the field of the regulation of armaments under article 26 of the Charter.

Furthermore, the Security Council might consider the advisability of establishing, under article 29 of the Charter, subsidiary organs for specific disarmament purposes, beginning with a committee, divided into regional sub-committees, to control the international transfer of conventional weapons.

(c) Machinery of Negotiation: the Conference of the Committee on Disarmament (CCD)

Because of their very complex nature, effective disarmament negotiations at the multilateral level can be undertaken only within a body of limited dimensions, operating by consensus.

The Conference of the Committee on Disarmament (CCD) has proved to be the most qualified forum for the achievement of substantive disarmament measures intended to have universal application.

The CCD should continue to function as the main multilateral negotiating body in the field of arms control and to carry out all of its responsibilities in the pursuit of effective agreements relating to the cessation of the arms race and to disarmament. The CCD should, inter alia, intensify its efforts in view of the elaboration of a comprehensive programme for disarmament negotiations.

It is widely recognized that the role of the CCD would be consistently enhanced by the association of those nuclear-weapon States which do not yet participate in its deliberations.

In addition, the CCD might be recommended to review its structures and methods of work in view of:

(a) envisaging a limited increase in its membership which would ensure a greater geographical and political balance in its composition;
(b) opening its meetings, under appropriate circumstances, to all interested United Nations Member States. Such States could participate as observers in plenary meetings, being allowed to submit written proposals and to take part in their discussion before the Committee. The same proposals would be circulated as official documents of the CCD.

While the present degree of autonomy and flexibility of the CCD should be maintained as an essential condition of the effectiveness of the negotiation process, a closer liaison between the CCD and the United Nations might be secured by requesting the CCD to address to the General Assembly a progress report following the spring session and periodic special reports on particular topics, as appropriate.

It could also be suggested that the Committee, at the beginning of its activities every year, should seek to reach a broad agreement on the work to be accomplished during its two sessions and to establish a methodical schedule of negotiations to be conducted within the period considered.

The work of the CCD could be further improved by the establishment - as soon as it is deemed appropriate by a sufficient convergence of views among the members - of functional working groups which would negotiate draft treaties or accord consideration, informally and in depth, to specific items, with the assistance of experts.

Finally, the CCD might be invited to consider the possibility of opening its plenary meetings to the public.

(d) Machinery for verification

While strengthening the world security system, on a parallel with progress made in the field of disarmament, the United Nations should consider the establishment of a permanent international organ for verification of multilateral disarmament measures.

Such a body, to be instituted by international agreement following appropriate studies and consultations, would operate in the framework of the United Nations. It would be designed to supervise, from both the technical and legal viewpoints, the implementation of treaties in force, so as to ensure full compliance with their provisions.

To this effect, the organ of verification should employ whatever technological and scientific means - such as sensing, sampling, recording, communicating and interpreting devices - might be usefully applied toward an effective verification of disarmament measures.

(e) United Nations Centre for Disarmament

The organization and functioning of the United Nations Centre for Disarmament should be carefully assessed with the aim of improving its effectiveness and capability, in order that it may:

(a) carry out, with the necessary expertise, studies and research as needed for the clarification of specific disarmament issues;

(b) provide broader information and stimulate a greater awareness on the part of international public opinion regarding disarmament problems.
ITALY

Working paper on international mechanisms for disarmament

The special session of the General Assembly devoted to disarmament provides an important opportunity to consider and to evaluate existing multilateral mechanisms and to make suggestions and recommendations for their improvement.

In a review of the adequacy of international disarmament machinery, the following elements should be considered:

(1) the vital interest of all nations in the outcome of disarmament negotiations and the need for a more conscious and direct participation of all States in disarmament endeavours;

(2) the special responsibility incumbent upon nuclear-weapon Powers and other militarily significant States and their primary role in effective progress toward disarmament, particularly nuclear disarmament;

(3) the desirability of a better co-ordination among bilateral, regional and multilateral efforts, with a view to over-all achievements toward the ultimate goal of general and complete disarmament;

(4) the necessity for a parallel strengthening of the international security system and of the establishment of adequate verification mechanisms in order to assure the effective implementation and the strict fulfilment of agreed disarmament measures.

Against this background, Italy believes that the special session should focus its attention on the following main components of the international disarmament machinery:

(a) United Nations General Assembly

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In view of rationalizing debates and rendering decision-making more effective, all disarmament items should be allocated to the First Committee, which should mainly concentrate its activity on disarmament and international security matters.

To this end, any other suitable revision of the procedures should be readily envisaged, bearing in mind the recommendations of the Ad Hoc Committee on the Review of the Role of the United Nations in the field of disarmament.
Ad hoc committees of the General Assembly could be set up to deal with issues deserving special consideration.

While the General Assembly should remain the regular forum for the annual review of disarmament problems, it might be appropriate to convene, in due course, a further special session for the specific purpose of:

(a) appraising the implementation of the Programme of Action;
(b) identifying guidelines for the next sequence of negotiations;
(c) considering and possibly adopting a comprehensive programme of disarmament.

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Consideration should be given to the specific contribution which the Security Council could make to disarmament progress.

To this effect, it is suggested that the Security Council should review the implementation of its responsibilities in the field of the regulation of armaments under Article 26 of the Charter.

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It is widely recognized that the role of the CCD would be consistently enhanced by the association of those nuclear-weapon States which do not yet participate in its deliberations.

In addition, the CCD might be recommended to review its structures and methods of work in view of:

(a) envisaging a limited increase in its membership which would ensure a greater geographical and political balance on its composition;
(b) opening its meetings, under appropriate circumstances, to all interested United Nations Member States. Such States could participate as observers in plenary meetings, being allowed to submit written proposals and to take part in their discussion before the Committee. The same proposals would be circulated as official documents of the CCD.

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It could also be suggested that the Committee, at the beginning of its activities every year, should seek to reach a broad agreement on the work to be accomplished during its two sessions and to establish a methodical schedule of negotiations to be conducted within the period considered.

The work of the CCD could be further improved by the establishment — as soon as it is deemed appropriate by a sufficient convergence of views among the members — of functional working groups which would negotiate draft treaties or accord consideration, informally and in depth, to specific items, with the assistance of experts.

Finally, the CCD might be invited to consider the possibility of opening its plenary meetings to the public.

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Such a body, to be instituted by international agreement following appropriate studies and consultations, would operate in the framework of the United Nations. It would be designed to supervise, from both the technical and legal viewpoints, the implementation of treaties in force, so as to ensure full compliance with their provisions.

To this effect, the organ of verification should employ whatever technological and scientific means — such as sensing, sampling, recording, communicating and interpreting devices — might be usefully applied toward an effective verification of disarmament measures.

(e) United Nations Centre for Disarmament

The organization and functioning of the United Nations Centre for Disarmament should be carefully assessed with the aim of improving its effectiveness and capability, in order that it may:

(a) carry out, with the necessary expertise, studies and research as needed for the clarification of specific disarmament issues,

(b) provide broader information and stimulate a greater awareness on the part of international public opinion regarding disarmament problems.

-233-
Working paper on a methodological investigation for computerized scanning of chemical literature

Introduction

A disarmament treaty prohibiting development, production and stockpiling of chemical weapons will need provisions for verification as well as other methods for strengthening confidence between the parties to the treaty. Different methods have been discussed in the CCD. The former leader of the Swedish delegation to the CCD, Minister of State, Mrs. Alva Myrdal, pointed out the potential value of collecting, systematizing and disseminating information contained in scientific and technical literature (ENCD/PV.391, 20 August 1968). This method has also been discussed at informal meetings with chemical experts at the Conference of the Committee on Disarmament.

Manual scanning of relevant literature is a time-consuming task. Work of this kind demands a wide coverage of journals and other open sources. However, there is today an increasingly large number of abstract publications which facilitate access to the world literature within a special subject. Many of these abstract publications appear also on magnetic tapes and are available for direct computer scanning. This facilitates further the following of the literature with a desired field. It therefore seemed worthwhile to investigate suitable means and methods for utilizing such data-based abstract publications and evaluate their possible applicability in connexion with a chemical weapons treaty.

Aims

The method for the computerized literature search should ideally catch only relevant items from the immense amount of papers and articles that are published.

When weighing manual versus computerized retrieval of literature, one must observe that computerized retrieval is advantageous when many combined concepts shall be watched. It is possible to look out, "manually", for material under the heading of one keyword, but to follow combinations of keywords requires a much larger effort. An evaluation of the size and usefulness of different databases has made it clear that the most comprehensive coverage will be obtained when several databases are searched simultaneously. However, this has not been applied in the study reported on in this working paper.

Investigation

1. In this study the computer-readable version of Chemical Abstracts (CA) was used, i.e. Chemical Abstracts Condensates (CAC). This data-base provides access
Chemical Abstracts contains references to chemical information included in more than 10,000 serial publications, printed all over the world. In 1977 Chemical Abstracts contained references to ca 10,000 papers, patents, reports and books. Chemical Abstract Condensates, which is issued weekly, contains the bibliographic description of every item abstracted in the Chemical Abstracts, plus the keywords used for the issue index. The bibliographic description includes, e.g., source document, bibliographic citations, document titles, names of chemical substances. The keyword index is produced by specialists in various subject areas.

The study consists of two parts. First a preparatory study was carried out on a material from five issues of Chemical Abstract Condensates within the subject field of biochemistry and organic chemistry. This material consisted of 26,488 references and was manually searched, read and analysed in order to find all relevant references.

The five issues of the printed version of Chemical Abstract Condensates used were read through by two chemists experienced in questions related to chemical warfare problems. References were selected by the readers according to the "most interesting subject" in the paper and with regard mainly to the degree of toxicity. The selected references were then reclassified by a highly qualified scientist in order to take into consideration also the concepts "novelty" and "military" interest.

Different kinds of search strategies were formulated and tested on the "known" material in order to find the most successful one, i.e., the search strategy which would retrieve the relevant references. This "known" material was also to be used as a standard for comparison with the output from the subsequent computerized search.

Secondly, in the main study the selected search strategies obtained in the preparatory study were applied to 20 subsequently published issues of Chemical Abstract Condensates, containing 128,740 references. The output, i.e., the lists of references, obtained by means of the applied search strategies, was treated in the same way as the material in the preparatory study, i.e., they were scanned by the two chemists and selected references classified by the scientist.

Formulation of search strategies

Two search strategies were formulated in the following way in order to retrieve the largest number of relevant references. Keywords were selected and compiled into different groups, and combined into the search strategies, which were tested. Two sets of combinations of these groups formed the search strategies finally used, Alfa and Beta respectively.

The groups and examples of pertinent keywords are briefly described in table 1.
Table 1. Description of keyword groups used in the search strategies

<table>
<thead>
<tr>
<th>Description</th>
<th>Example of pertinent keywords</th>
<th>Number of keywords in the group</th>
</tr>
</thead>
<tbody>
<tr>
<td>General expressions of toxicity</td>
<td>TOXIN</td>
<td>4</td>
</tr>
<tr>
<td>General expressions of warning or danger</td>
<td>DANGER</td>
<td>21</td>
</tr>
<tr>
<td>Substances with effects on skin and mucous membrane</td>
<td>MUSTA 1/</td>
<td>3</td>
</tr>
<tr>
<td>Organs, i.e. lung</td>
<td>PULMON 1/</td>
<td>9</td>
</tr>
<tr>
<td>Cholinesterase inhibitors</td>
<td>CARBAM 1/</td>
<td>7</td>
</tr>
<tr>
<td>Cholinergic system</td>
<td>CHOLINEST 1/</td>
<td>4</td>
</tr>
<tr>
<td>Organs and functions</td>
<td>RESPIRAT 1/</td>
<td>6</td>
</tr>
<tr>
<td>Chemical structures</td>
<td>FLUOR</td>
<td>6</td>
</tr>
<tr>
<td>Chemical warfare agents</td>
<td>SARTIN</td>
<td>27</td>
</tr>
<tr>
<td>Laboratory methods</td>
<td>ISOLAR 1/</td>
<td>6</td>
</tr>
<tr>
<td>Gases and aerosols</td>
<td>GAS 1/</td>
<td>5</td>
</tr>
<tr>
<td>Toxic effects</td>
<td>VOMIT 1/</td>
<td>32</td>
</tr>
<tr>
<td>Delimitating or inhibiting effects</td>
<td>BLOCK 1/</td>
<td>7</td>
</tr>
<tr>
<td>Total number of keywords</td>
<td></td>
<td>137</td>
</tr>
</tbody>
</table>

1/ Parts of words can be used as keywords.

Alfa was intended to retrieve the largest possible number of relevant references within a reasonable amount of the references resulting from the computer output, i.e. recall should be as high as possible. Beta should result in a still more reduced output as compared to Alfa without losing too many relevant references, and thereby resulting in giving a higher precision.

The measures used to evaluate the search strategies were expressed as follows:

Recall = \[
\frac{\text{Number of retrieved relevant references}}{\text{Number of all relevant references in the database}}
\]

Precision = \[
\frac{\text{Number of retrieved relevant references}}{\text{Number of all retrieved references}}
\]

Size of reduced database (per cent) = \[
\frac{\text{number of retrieved references}}{\text{total number of references in the database}} \times 100
\]
Results

Some of the results of the study are presented in table 2.

Table 2. Results obtained by the search strategies Alfa and Beta, preparatory and main studies

<table>
<thead>
<tr>
<th>Search Profile</th>
<th>Preparatory study</th>
<th>Main study</th>
<th>Total No. of retrieved references (output)</th>
<th>% of original database</th>
<th>No. of retrieved relevant references</th>
<th>Recall</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual search</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparatory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfa</td>
<td></td>
<td></td>
<td>1,138</td>
<td>4.3</td>
<td>31</td>
<td>0.89</td>
<td>0.03</td>
</tr>
<tr>
<td>Beta</td>
<td></td>
<td></td>
<td>260</td>
<td>1.0</td>
<td>22</td>
<td>0.63</td>
<td>0.09</td>
</tr>
<tr>
<td>Main study</td>
<td></td>
<td>Alfa</td>
<td>5,019</td>
<td>3.9</td>
<td>88</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beta</td>
<td>1,139</td>
<td>0.88</td>
<td>60</td>
<td></td>
<td>0.05</td>
</tr>
</tbody>
</table>

It is impossible to give recall in the main study because of the lack of knowledge of the total number of relevant references in the material.

It was calculated that the probability of retrieving new information relevant to the chemical warfare-subject by the described method is fairly high (p > 0.8), assuming that such information appears in at least two or more different abstracted references.

Conclusions

The present methodological investigation has shown it is possible to formulate effective search strategies for computerized searching of databased literature references for information concerning chemical warfare agents. The method makes it possible to substantially diminish the amount of work needed for searching manually the corresponding amount of literature. The results imply that with search strategies of the types used it is possible to reduce the database (in this investigation Chemical Abstracts Condensates) to 1-4 per cent of its original size, while still retaining 63-89 per cent of relevant references in the material.

It seems possible to improve the method and also to apply it to several more databases.
Recognizing the valuable and important work carried out by the Ad Hoc Group and presented to the CCD in its report of 14 March 1978 (CCD/558), taking note of the suggestion by the Ad Hoc Group that it conduct additional work and also of a similar suggestion by the Japanese delegation (CCD/PV.776), the CCD decides that the Ad Hoc Group should continue its work by studying the scientific and methodological principles of a possible experimental test of a global network of seismological stations of the kind which might be established in the future for the international exchange of seismological data under a treaty prohibiting nuclear weapon tests, and a protocol covering nuclear explosions for peaceful purposes which would be an integral part of the treaty.

The studies should include the elaboration of instructions and specifications for the following items:

- data to be routinely produced at participating stations (level I data)
- data format and procedures for level I data transmission through the WMO communication network
- procedures to be used for data analysis at data centres
- format and procedures for the exchange of waveform data (level II data)

The organization and procedures of the work of this Group shall remain the same as those defined by the decision of the Committee of 22 July 1976. The Ad Hoc Group will hold its first meeting under its new mandate during the week beginning 24 July 1978. The Group should present a progress report after each of its sessions. The Group should report the results of its work to the Committee during its spring session of 1979. After considering the final report of the Ad Hoc Group the Committee will consider the question of desirability of carrying out an experimental exercise.
Report of the Ad Hoc Working Group to Discuss and Elaborate a Comprehensive Programme for Disarmament

1. On 25 August 1977, the Conference of the Committee on Disarmament adopted a consensus decision to set up, at the beginning of its 1978 spring session, an Ad Hoc Working Group to discuss and elaborate a comprehensive programme for disarmament.

2. At its thirty-second session in 1977, the General Assembly adopted resolution 32/80 under the item entitled "Effective measures to implement the purposes and objectives of the Disarmament Decade", in which the Assembly, inter alia, took note of the above-mentioned decision of the CCD and requested the Committee to continue its work on this subject and to submit a progress report to the General Assembly at its special session devoted to disarmament, to be held in May and June 1978.

3. At its 776th plenary meeting on 2 March 1978, the Conference of the Committee on Disarmament, in accordance with the decision reached at its 765th plenary meeting on 25 August 1977, adopted by consensus the terms of reference establishing the Ad Hoc Working Group to discuss and elaborate a draft comprehensive programme for disarmament. By those terms of reference the Group would (a) take as its basic working tests all Committee documents on the subject of a comprehensive programme for disarmament, starting with the 1961 USSR/USA Joint Statement of Agreed Principles for Disarmament Negotiations and also taking into account other documents that may be submitted to the Committee during the course of its work, both by members and by non-members of the CCD: (b) request the Secretariat to circulate as CCD documents all documents submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament on a comprehensive programme for disarmament: (c) be guided by the CCD's procedural decision adopted at its 746th plenary meeting on 21 April 1977, relating to the establishment of ad hoc working groups; and (d) submit a report on its work to the CCD before the end of the 1978 spring session.

4. On 20 March 1978, the Ad Hoc Working Group held its first meeting and devoted it to the consideration of procedural and organizational matters, particularly with respect to documentation for its work. At that meeting, it considered three papers prepared by the Secretariat (a) a paper dated 6 March 1978, containing an updated version, requested by Nigeria, of the document of 3 March 1977 entitled "Informal Background Paper on Comprehensive Negotiating Programme": (b) a note by the Secretariat dated 13 March 1978, containing for the Group's consideration in connexion with a request by India on behalf of the group of 15 for a tabulation of documents on the comprehensive programme for disarmament (1) a tentative and preliminary list of relevant documents on the comprehensive programme for disarmament to be tabulated: and (2) a preliminary and tentative list of headings that might be used for arranging the proposals to be
so tabulated: and (c) a note by the Secretariat dated 20 March 1978, containing a list, for the Group's consideration, of working papers and proposals on a comprehensive programme for disarmament submitted to the Preparatory Committee for the Special Session of the General Assembly Devoted to Disarmament.

At its second meeting on 22 March 1978, the Ad Hoc Working Group after considering further the papers submitted by the Secretariat above, decided to request the Secretariat to prepare the said tabulation, based on the lists of documents and headings contained in the Secretariat's papers above and also taking into account the suggestions made by various delegations concerning those lists.

5. At its meeting on 3 May 1978, the Ad Hoc Working Group took note of the documents prepared by the Secretariat in accordance with its request which would be useful for future work on the comprehensive programme for disarmament. In view of the lack of time, however, and bearing in mind the various options available to the General Assembly with respect to this subject, the Ad Hoc Working Group decided to recommend to the Conference of the Committee on Disarmament that the tabulation paper (CCD/567) should be annexed to the Committee's special report to the Special Session of the General Assembly Devoted to Disarmament.
Terms of reference for the Ad Hoc Working Group on a Comprehensive Programme of Disarmament

In accordance with the decision reached at its 765th meeting on 25 August 1977, the Conference of the Committee on Disarmament hereby establishes an Ad Hoc Working Group of the Committee to discuss and elaborate a draft comprehensive programme of disarmament to be submitted to the CCD for consideration.

The Ad Hoc Working Group will have as the basic texts for its work all the working papers and draft proposals on the comprehensive programme of disarmament which have been submitted to the CCD starting with the Joint Statement of agreed principles for disarmament negotiations of 1961. It shall also take into account other documents that may be submitted to the CCD during the course of its work both by members and non-members of the CCD. The Committee requests that the Secretariat circulate as CCD documents those documents and proposals on the comprehensive programme of disarmament which have been or may be submitted to the Preparatory Committee of the Special Session of the United Nations General Assembly Devoted to Disarmament.

In discharging its functions the Ad Hoc Working Group will be guided by the decision of the CCD of 21 April 1977 relating to the establishment of Ad Hoc Working Groups.

The Ad Hoc Working Group will submit a report on the work of the elaboration of the Comprehensive Programme of Disarmament to the CCD before the end of its spring session.

The Committee requests the Secretariat to provide necessary assistance to the Ad Hoc Working Group including interpretation and translation services and preparing unofficial summaries of the Working Group's proceedings.
Special report of the Conference of the Committee on Disarmament to the special session of the General Assembly devoted to disarmament

For the text, see Official Records of the General Assembly, Tenth Special Session, Supplements Nos. 2 and 2A
Schedule of meetings of the Conference of the Committee on Disarmament for the summer session

(Adopted at the 795th Plenary Meeting, on 27 July 1978)

Plenary meetings

Plenary meetings will continue to be held on Tuesday and Thursday at 10.30 a.m., unless decided otherwise. The agenda for the plenary meetings, adopted on 15 August 1968, reads as follows:

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

"Under this heading, members may wish to discuss measures dealing with the cessation of testing, the non-use of nuclear weapons, the cessation of production of fissionable materials for weapons use, the cessation of manufacture of weapons and reduction and subsequent elimination of nuclear stockpiles, nuclear-free zones, etc.

"2. Non-nuclear measures.

"Under this heading, members may wish to discuss chemical and bacteriological warfare, regional arms limitations, etc.

"3. Other collateral measures.

"Under this heading, members may wish to discuss prevention of an arms race on the seabed, etc.

"4. General and complete disarmament under strict and effective international control.

"The Co-Chairmen note the recognized right of any delegation to raise and discuss any disarmament subject in any meeting of the Committee."

INFORMAL MEETINGS OF THE CCD

11-27 July*

- Informal meetings of the CCD, as required, to discuss the CCD Summer Session schedule of work.

* During the period 24-28 July, the Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events will meet to study the scientific and methodological principles of a possible experimental test of a possible global network of seismological stations for the international exchange of seismological data under a treaty prohibiting nuclear weapon tests, and a protocol, which would be an integral part of the treaty, covering nuclear explosions for peaceful purposes.
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Description</th>
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<tr>
<td>31 July-4 August</td>
<td>Informal meetings of the CCD to consider the progress in the 24-28 July deliberations of the Group of Scientific Experts.</td>
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<tr>
<td>7-11 August</td>
<td>Informal meetings of the CCD on a comprehensive nuclear test ban. It is understood that there will be a statement on the status of the trilateral negotiations on the subject.</td>
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<tr>
<td>14-18 August</td>
<td>Informal meetings of the CCD, with participation of experts, on new types and systems of weapons of mass destruction.</td>
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<tr>
<td>21-25 August</td>
<td>Informal meetings of the CCD on CW. It is understood that there will be a statement on the status of the bilateral negotiations.</td>
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<tr>
<td>Week Prior to</td>
<td>Informal meetings of the CCD to consider the draft report to the United Nations General Assembly.</td>
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<tr>
<td>Adjournment**</td>
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** On 10 April 1975, the Committee decided, inter alia, that the report of the Conference on its activities shall be transmitted to the United Nations General Assembly on the last Thursday in August unless decided otherwise. Also, the Committee is free to convene at any time during the remainder of the year upon recommendation of the Co-Chairmen after full consultations with Committee members, in order to conduct negotiations on the priority items on its agenda.
1. Introduction

The development of technical military equipment has accelerated considerably over the past few decades. On the basis of the results of development obtained in various sectors of science and technology, new and more up-to-date military equipment and armaments are appearing and proliferating, and this quite rapidly. The emergence of a large number of new types of military equipment inevitably leads to the intensification of the arms race, since every army is anxious not to lag behind the others.

The intensive development of science and technology may lead to the emergence of new types of weapons of mass destruction which differ qualitatively from the preceding ones, while their mass destruction effect may be identical with or greater than that of existing types of weapons of mass destruction.

The emergence of new types of weapons of mass destruction would considerably intensify the arms race and would require vast material expenditure, since a qualitatively new type of weapon would upset the balance of power and would cast doubt on all the results achieved earlier at disarmament conferences.

These considerations, and awareness of the possibilities of scientific and technological progress, justify alarm concerning the development of new types of weapons of mass destruction. This was realized by the Soviet Union, which drew up and submitted to the thirtieth session of the United Nations General Assembly a draft agreement on the "Prohibition of development and manufacture of new types of weapons of mass destruction and new systems of such weapons" (CCD/511).

The United Nations General Assembly considered that the question deserved attention and transmitted the draft agreement to the Geneva Committee on Disarmament, in which negotiations were begun in 1976 with the participation of experts. During these negotiations the first questions to be clarified were as follows:

The extent to which there is a real possibility of the development of new types of weapons of mass destruction;

The scientific and technological areas in which a development in that direction may be expected;

The particular new types of weapons of mass destruction that may be foreseen;

The list to be annexed to the above-mentioned draft agreement.
Several of these questions have so far been discussed at unofficial meetings of experts. At the most recent meetings, agreement began to crystallize on the need for including four categories of new types of weapons of mass destruction in the aforesaid list.

Of these four categories, that of infrasound weapons deserves special attention, since, on the basis of progress made in acoustics, the development of such equipment already seems possible in the foreseeable future.

2. **Infrasound**

Infrasound denotes elastic waves which are similar to sound waves, but have frequencies below the range of those audible to human beings. The upper limit of the infrasound range is generally accepted to be that of frequencies 16-25 hertz. The lower limit of the infrasound range has not been determined. Oscillations of tenths and even hundredths of a hertz, i.e. with periods of some ten seconds, may be of practical interest.

Infrasounds occur in the noise of the atmosphere, forests and seas; their source is atmospheric turbulence and wind (for example, the "voice of the sea", that is to say, infrasound oscillations caused by wind eddying on the crests of waves). Other sources of infrasound oscillations are atmospheric discharges (thunder), and also explosions and artillery fire.

Tremors and vibrations of infrasound frequencies in the earth's crust are caused by a wide variety of sources - explosions, clouds and other exciters.

A characteristic of infrasound is low absorption in various media, as a result of which infrasound waves in the air, water and earth's crust can propagate over very long distances without noticeable attenuation. It is easy to prove on the basis of acoustics that the propagation distance of infrasound waves is in inverse proportion to their frequency. For example, infrasounds at frequencies of up to 10-15 hertz will propagate over several hundred kilometres. Another peculiarity of infrasound waves is that it is practically impossible to set up any obstacles to their propagation path, since even large and solid installations have absolutely no effect.

The reception and measurement of infrasound oscillations is effected by microphones, hydrophones and geophones, "electro-acoustic" transformers or vibrometers.

3. **Harmful effects of infrasound on the human organism**

The human being does not hear infrasounds, although some of them are received. Yet infrasounds are received not by the organs of hearing, but by the organism as a whole. The effects of infrasound oscillations on the human organism are generally harmful.

Even slight infrasound radiations at certain frequencies induce headaches, giddiness, nausea, disorders of vision, throat spasms, breathing disorders and "psychotropic" effects, causing a feeling of fear and loss of consciousness. In some cases even a single exposure to low-power infrasound radiation can lead to epilepsy.
Certain researchers have discovered that the above-mentioned psychotropic effect is caused by infrasound at a frequency of 7 hertz. It has been determined that this frequency can be particularly harmful because it corresponds to the alpha-rhythm frequencies of the brain.

On the basis of the above-mentioned phenomena, it has been determined that a low-power infrasound affects the biocurrents of the brain and the nervous system as a whole, that is to say, a person's psychic condition, and may lead to the loss of military and defensive capacity.

Exposure to powerful infrasound radiations may lead to lethal discharges through injury to human internal organs.

Radiation of human beings by powerful infrasound leads to strong vibration of their internal organs, and that, in turn, can lead to the rupture of these organs, and to overloading of the cardiovascular system.

Research has shown that the harmful effect of infrasound on the human organism is most dangerous at frequency 7-8 hertz, because this corresponds to the resonance frequency of the human internal organs. In these cases, the "resonance" phenomenon occurs and the human internal organs are ruptured.

These effects of infrasound on human beings - feelings of acute pain, pathological changes in the human organism and fatal outcome - first began to be known after the Second World War, for it was at that time in connexion with the appearance of powerful jet-engine rockets and supersonic aircraft, that research was started on the effects of powerful sound radiation on the human being.

It was found that irreversible changes in the human organism will occur in the event of infrasound radiations even with an intensity below 100 decibels.

4. Possible types of infrasound weapons

Specific military systems of infrasound weapons of mass destruction of human life based on the harmful effects of infrasound radiations on the human organism have now become possible. The potential varieties of this new type of weapon of mass destruction are:

Psychotropic types of infrasound weapons;

Types of infrasound weapons for injuring human internal organs.

Examples of these types of weapons can even be found in world scientific and technological literature.

In order to manufacture an infrasound weapon, it is possible, for example, to use a simple aircraft jet engine, operating at a low frequency, to one end of which a long open tube is attached.

According to engineering calculations, infrasound oscillations might also be generated by a screw several metres in diameter placed in a tube and actuated by a gas-turbine aircraft engine.

The size of these structures is of course too large and their mobility is
limited, but as science and technology develop, the size and weight parameters of
the structures can be considerably reduced.

Research has shown that certain characteristic properties of infrasound can be
used as a weapon of mass destruction. The most important of these is the great
propagation distance and also the fact that this propagation cannot be hindered,
that is to say, that there are practically no methods of defence against the
effects of infrasound.

This means that the use of infrasound weapons can cause the mass destruction
of people in shelters and in armoured military equipment.

The results of technological and economic analyses of the destructive effects
of infrasound also serve as arguments for its military use.

On the basis of these analyses, it has been discovered that the specific
indices of the destructive effect of this new weapon are fully acceptable.
Calculations have shown that the destruction of human beings would theoretically
require considerably less expenditure by infrasound weapons than by any existing
type of weapons of mass destruction.

5. Conclusions

It is clear from the foregoing that infrasound can in future become the basis
of one of the dangerous types of new weapons of mass destruction. On the basis
of scientific and technological developments, the appearance of these new types of
weapons of mass destruction can already be expected in the foreseeable future.

All this leads to the unequivocal conclusion that the scope of the agreement
on the prohibition of the development and manufacture of new types of weapons of
mass destruction must also be extended to the military use of infrasound weapons of
mass destruction, that is to say, infrasound weapons of mass destruction must also
be included in the list annexed to the draft agreement.

Finally, it should be noted that the Soviet Union's initiative and draft
agreement of 1975 in no way hamper scientific and technological research or the
freedom of scientific and technological advancement, but are directed only towards
limiting the use of scientific and technological achievements for military
purposes; accordingly, where infrasound is concerned, it is proposed only to
prohibit its use as a weapon of mass destruction.

This prohibition would in no way serve as an obstacle to the development of
acoustics for peaceful purposes. The prohibition of types of infrasound weapons
of mass destruction would not restrict scientific and technological progress, but
would simply protect mankind from the emergence of one of the new and very
dangerous types of weapons of mass destruction.
Sixth progress report of the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events

1. In pursuance of the decision taken by the CCD on 4 May 1978 (CCD/570) that the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events conduct additional work, the Group held its sixth plenary session from 24 to 28 July 1978 in Geneva, under the Chairmanship of Dr. Ulf Ericsson of Sweden.

2. Scientific experts and representatives of the following Member States of the CCD participated in the session: Bulgaria, Canada, Czechoslovakia, Egypt, Federal Republic of Germany, German Democratic Republic, Hungary, India, Italy, Japan, Netherlands, Poland, Sweden, Union of Soviet Socialist Republics, United Kingdom and United States of America.

3. By its decision of 18 July 1978, the CCD had invited Austria to participate in the work of the Ad Hoc Group. Thus scientific experts and representatives of the following States not members of CCD also participated in the sixth session of the Ad Hoc Group: Austria, Australia, Denmark, Finland, New Zealand and Norway.

4. The Group agreed, inter alia, on a provisional table of contents for its second report, with main headings as follows:

   Chapter 1. Summary of the report
   Chapter 2. Background and mandate
   Chapter 3. Instructions and specifications for data to be routinely produced at participating stations (Level I data)
   Chapter 4. Instructions and specifications for data format and procedure for Level I data transmission through the WMO communications network
   Chapter 5. Instructions and specifications for procedures to be used for data analysis at data centres
   Chapter 6. Instructions and specifications for format and procedures for the exchange of wave form data (Level II data)
   Chapter 7. Recommendations

5. After thorough discussion, the Group agreed on guidelines for working groups to produce drafts on chapters 3, 4, 5 and 6 of its second report and established the corresponding working groups headed by the following convenors:
Dr. Kárník (Czechoslovakia), Dr. Suyehiro (Japan), Dr. Dahlman (Sweden) and Dr. Thirlaway (United Kingdom). The Ad Hoc Group also agreed on a tentative schedule for the further work of the working groups, including meetings on 27 and 28 July 1978.

6. The Ad Hoc Group suggested that a representative of the WHO be invited by the CCD to participate informally in the work of the Group in relation to the transmission of data through the WHO communication network.

7. The Group also established a draft agenda for its seventh and eighth sessions, tentatively to be convened at the end of February and the end of April 1979, respectively. In particular, the Group agreed, subject to decision by the CCD, to hold its next session in the Palais des Nations in Geneva from 19 February to 2 March 1979.

8. However, as a result of the discussions of the Ad Hoc Group, it became clear that the time originally allotted by the CCD for the final report would be insufficient to provide as detailed and comprehensive results as the CCD might wish. Therefore, the Ad Hoc Group asked its Chairman to consult with the CCD about the possibility to further continue its work to prepare its final report.
Letter dated 14 August 1978 from the Chargé d'Affaires a.i. of the Permanent Mission of Finland to the United Nations Office at Geneva addressed to the Special Representative of the Secretary-General

Upon instruction from my Government, I have the honour to forward to you herewith a study entitled "An Analytical Technique for the Verification of Chemical Disarmament - Trace Analysis by Glass Capillary Gas Chromatography with Specific Detectors", prepared for the Ministry for Foreign Affairs of Finland by the Advisory Board for Disarmament. I would very much appreciate it if the paper could be distributed in the Conference of the Committee on Disarmament as an official document.

Additional copies of the study may be obtained from the Ministry for Foreign Affairs, Helsinki.

(Signed) Garth CASTREN
Chargé d'Affaires a.i.

* A limited distribution of this document has been made to the members of Conference of the Committee on Disarmament.