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APPENDIX II

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CONFERENCE ON DISARMAMENT

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LETTER DATED 25 JUNE 1985 ADDRESSED TO THE PRESIDENT OF THE CONFERENCE ON DISARMAMENT BY THE PERMANENT REPRESENTATIVE OF CHINA FORWARDING EXTRACTS FROM THE SPEECH BY CHAIRMAN DENG XIAOPING OF THE CENTRAL MILITARY COMMISSION, MADE ON 4 JUNE 1985, AND THE SPEECH BY THE GENERAL SECRETARY OF THE COMMUNIST PARTY OF CHINA, MR. HU YAOBANG, MADE ON 6 JUNE 1985

I have the honour to forward to you herewith the extracts from the speech by Chairman Deng Xiaoping of the Central Military Commission at its enlarged meeting on 4 June 1985 and the speech by the General Secretary of the Communist Party of China, Mr. Hu Yaobang, at the banquet in honour of peace activists from various countries on 6 June 1985.

I would be grateful if the texts could be circulated as an official document of the Conference on Disarmament.

(Signed) (Qian Jiadong)

Ambassador

Permanent Representative of China
to the Conference on Disarmament

Extracts from the speech by Chairman Deng Xiaoping of the
Central Military Commission at its enlarged meeting

At an enlarged meeting of the Central Military Commission on 4 June 1985, Chairman Deng Xiaoping announced that the Chinese Government had decided to reduce the People's Liberation Army (PLA) by 1 million men.

Deng Xiaoping said that the danger of world war remained. The factors for war were likely to increase due to the ongoing arms race of the two super-Powers. However, the people wanted peace and opposed war. The world forces for peace would grow more rapidly than the forces for war. He also said that the Chinese Government always held high the banner of opposing hegemonism and safeguarding world peace, pursued an independent foreign policy and resolutely stood by the forces for peace. As the forces for peace grew throughout the world, it was possible that a large-scale world war would not break out for a fairly long time to come and that the prospects for world peace were hopeful.

Deng Xiaoping stressed that China wanted to concentrate on its economic development so as to build itself into a strong and modernized socialist country. China needed a peaceful international environment and had been working hard to create and safeguard such an environment. Economic development represented our over-all interest to which everything else should be subordinated.

OUR COMMON HISTORICAL DUTY

Speech by CPC General Secretary Hu Yaobang at the banquet
in honour of peace activists from various countries on
6 June

It gives me much pleasure today to meet with the peace activists from over 20 countries. I would like to take this opportunity to express the keen concern of the Communist Party of China and the Chinese people over the issue of peace and reiterate China's commitment to the obligation of safeguarding world peace.

We have stated on many occasions that the two paramount issues in the world today are those of peace and development, and that peace is the prerequisite for development. It is our sincere hope that all countries of the world will live in harmony and work for common prosperity. These two issues involve all the countries and all the people of the world, and affect the destiny of our future generations. Every statesman endowed with foresight should reflect on his responsibility for peace and security of the people of his own country and of the whole world, indeed for the survival and development of the entire human race. Doing so, he cannot but adopt the only wise alternative in approaching the issue of war and peace, that is, upholding peace on the basis of full respect for the independence and sovereignty of each and every country.

I am optimistic about the future of the mankind. I am equally optimistic about the preservation of world peace. Although the danger of war still exists, I believe firmly that, provided that people of the whole world and all the peace-loving countries unite and take practical action in a joint effort to prevent a new world war, there will be good prospects for lasting world peace. The practical actions most important today should be aimed at urging the super-Powers, from different angles and by various means, to halt the arms race, especially the nuclear arms race and the arms race in space and the conventional arms race as well, and equally needed are actions aimed at urging all countries involved in international

disputes to settle them through peaceful means. Peace movements the world over are waging a tenacious struggle towards this end. Our 1 billion Chinese people are prepared to join hands with them in unremitting efforts for world peace.

We are realists. It is my view that, under the present international circumstances, it is necessary for a country to have its national defence. But measures in this field should be appropriate and defensive in nature. As an ancient Chinese saying aptly put it "Unity of will is an impregnable fortress." The security of a country, in the final analysis, rests mainly on the unity of its people. Blind relief in armed force and weaponry and in unceasing arms expansion and war preparations at the expense of people's welfare are bound eventually to undermine the foundation of the national security of the country involved. Proceeding from this belief, we are now going all out to achieve socialist modernization, to develop the productive forces of our society and to gradually raise the living standard of our people. China is opposed to arms race and under no circumstances will China take part in it. We are, of our own accord, cutting down on our armaments and reducing our armed forces. China pursues an independent and peaceful foreign policy, and will never enter into alliance or establish strategic relations with any of the big powers. China desires to maintain friendly relations with all the countries in the world. This is our fundamental national policy. As you all know, China, being a large country, has many things to do. Nonetheless, all our work can be summed up in two words: development and peace. We the Chinese leaders are concerned not only with the development of our country, but also with world peace. Every advance made by China in her development adds to the forces for peace in the world. In this sense, I too am a peace activist and working together with the friends present here for the cause of world peace.

I was delighted to learn that, at the peace forum, friends from different countries aired their views freely, and focused on the solemn theme of safeguarding world peace in a spirit of mutual respect and seeking common ground while setting aside differences, without adopting any documents. This method is very good and very significant. We hope to conduct such free and meaningful dialogues with more friends from different countries.

Finally, I invite our friends to visit other parts of our country and see how our people are working for the peaceful development of their homeland. You are most welcome to give us your advice.

CHINA

WORKING PAPER

DESTRUCTION OF CHEMICAL WEAPONS

Element V of working paper CD/443 (1984, China) entitled "Proposals on Major Elements of a Future Convention on the Complete Prohibition and Total Destruction of Chemical Weapons" contains the following provisions:

- 2. All chemical weapon stocks should be totally destroyed except for dual-purpose chemical agents which, as agreed upon, may be diverted for peaceful uses. Destruction should commence at the earliest possible date after entry into force of the Convention and should be completed within 10 years at the latest.
- 3. In order to eliminate as early as possible the threat to mankind of chemical warfare, States in possession of chemical weapons should in the first place destroy stocks of the most toxic and dangerous types of chemical weapons, e.g. supertoxic lethal agents such as VX, Soman, Sarin, Tabun, mustard gas, etc.

The delegation of the People's Republic of China now proposes further that:

- The States Parties concerned destroy their chemical weapon stocks proportionally and in phases;
- The destruction quantities in each phase by the States Parties concerned be determined by the formulae for calculating the stockpiled equivalent and destruction quantity as specified in Annex ...

Annex

STOCKPILED EQUIVALENT OF CHEMICAL WARFARE AGENTS

List of contents

1. Introduction
2. Toxicity Intensity (TI)
3. Stockpiled Equivalent (SE) of Chemical Warfare Agents
4. Illustrations of Application
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 - 4.2. Illustrative Calculation of Destruction Quantity (W_{des})
5. Discussion and Conclusion

1. Introduction

The destruction of existing chemical weapon stockpiles is one of the most important elements of the future Convention on the prohibition of chemical weapons and would be a step of great practical significance toward eliminating the threat of chemical warfare (CW). In this connection, agreement seems to have been reached on the following:

- Each State Party in possession of chemical weapons will start destroying its stockpile at a certain time after the entry into force of the Convention and complete the process within 10 years.
- No State Party possessing such stockpiles will gain any military advantage through the destruction process.

As regards the order of destruction, various proposals have been put forward, for instance, destruction of the most toxic and dangerous types of chemical weapons first, alternate destruction of CW agents of different toxicities and other options. Whichever order is applied, it is essential to determine how many tons of a CW agent a State concerned must destroy in a given phase. This paper is an attempt in this direction.

Till now, the stockpiled weight of chemical weapons or CW agents has been used as the most important measurement of the CW capability of a State. Under ordinary circumstances, this is sufficient. However, if this were to be used as the basis for balanced destruction of chemical weapons, the drawbacks are obvious, for CW capability is determined by both the quantity and the quality, i.e. toxicity, of CW agents.^{*/} Therefore, it is necessary to develop a new concept which will take into account the two aspects when estimating CW capability.

2. Toxicity Intensity (TI)

Definition: The Toxicity Intensity of a CW agent is defined as the weight of lives harmed (in the case of harmful agents) or killed (in the case of lethal agents) by one milligramme of the agent.

^{*/} For the purpose of this paper, other factors affecting CW capability, such as the efficiency of weapon systems and the level of training and organization of personnel, are not reckoned.

It is clear that the TI is the reciprocal of the lethal dose (LD, in the case of lethal agents) or the effective dose (ED, in the case of harmful agents), i.e.

$$TI = 1/LD \text{ (or ED)} \quad (I)$$

It is expressed as kg/mg.

For the sake of reliability, the median lethal dose (LD_{50}) or the median effective dose (ED_{50}) is always used instead of LD or ED, so the above formula can be converted into

$$TI = 1/LD_{50} \text{ (or } ED_{50}) \quad (II)$$

This is tantamount to introducing a constant coefficient into Formula (I) which, being identical for all States possessing chemical weapon stockpiles, will not affect the correlation in their CW capabilities.

3. Stockpiled Equivalent (SE) of CW Agents

Definition: The product of the stockpiled weight of a CW agent and its Toxicity Intensity is referred to as the Stockpiled Equivalent of the CW agent. That is,

$$SE = W \cdot TI \quad (III)$$

Obviously, there can be two kinds of SE, i.e. lethal SE (for lethal agents) and harmful SE (for harmful agents). SE can be expressed in any unit or weight (in kilogrammes, for example), but its values do not represent the actual quantities of stockpiled CW agents. The physical significance of SE is the theoretical weight of the casualties caused by W tons of CW agents. Hence, SE is a quantitative expression of the CW capability of a State.

The formula shows that the CW capability of a State is in direct proportion to the TI as well as the weight of its stockpile.

4. Illustrations of Application

4.1. Illustrative Calculation of SE

Assuming that Country A possesses two kinds of CW agents, CWA_1 and CWA_2 , and Country B possesses CWA_2 and CWA_3 , with the following weights and TIs respectively:

$W_{CWA_1}(A) = 100 \text{ tons,}$	$TI_{CWA_1} = 5 \text{ kg/mg;}$
$W_{CWA_2}(A), (B) = 200 \text{ tons,}$	$TI_{CWA_2} = 20 \text{ kg/mg;}$
$W_{CWA_3}(B) = 100 \text{ tons,}$	$TI_{CWA_3} = 10 \text{ kg/mg;}$

Then, according to Formula (III), the SE of each CW agent is:

$$SE_{CWA_1} = 0.5 \times 10^{12} \text{ kg}$$

$$SE_{CWA_2} = 4 \times 10^{12} \text{ kg}$$

$$SE_{CWA_3} = 1 \times 10^{12} \text{ kg}$$

and the total SE of each country is:

$$SE_{total(A)} = 4.5 \times 10^{12} \text{ kg}$$

$$SE_{total(B)} = 5 \times 10^{12} \text{ kg}$$

The values of $SE_{total(A)}$ and $SE_{total(B)}$ show that, though the two countries are equal in terms of stockpiled weight (300 tons each), the CW capability of Country B is in fact 11.1 per cent (i.e. 0.5×10^{12} kg) higher than Country A, because their stockpiles contain different kinds of CW agents. Thus, the SE concept truly reflects the CW capabilities of the two countries, which would be impossible if the stockpiled weights alone were taken into consideration.

4.2. Illustrative Calculation of Destruction Quantity (W_{des})

From the SE conversion Formula (III) can be derived Formula (IV) for calculating W_{des} .

$$\begin{aligned} W_{des} &= K \cdot SE_{total} \cdot TI^{-1} \\ &= SE_{des} \cdot TI^{-1} \\ &= SE_{des} \cdot LD_{50} \text{ (or } ED_{50}) \end{aligned}$$

where W_{des} : the actual weight of a CW agent to be destroyed by a State in one phase of destruction

K: the agreed destruction percentage in that phase

SE_{total} : the total Stockpiled Equivalent of the State

TI, LD_{50} or ED_{50} : the Toxicity Intensity, the median lethal dose or median effective dose of the CW agent to be destroyed in that phase

SE_{des} : the Stockpiled Equivalent to be destroyed by the State in that phase

In Formula (IV), K is an agreed constant and SE_{total} , a set value for any given State. Therefore, the W_{des} of an agent to be destroyed is in inverse proportion to its TI. In this way, a quantitative link is established between the destruction quantity and toxicity of the CW agent

to be destroyed, thereby making it possible to determine the quantity of specific kinds of stockpiled agents to be destroyed by different States.

Assuming that the two above-mentioned countries, A and B, are each to destroy one kind of CW agent at an agreed ratio of 10 per cent in a certain phase, then each country should destroy 10 per cent of its total Stockpiled Equivalent no matter which agent is to be destroyed. Thus,

$$\begin{aligned}SE_{des}(A) &= K \cdot SE_{total}(A) \\ &= 4.5 \times 10^{11} \text{ kg} \\ SE_{des}(B) &= K \cdot SE_{total}(B) \\ &= 5 \times 10^{11} \text{ kg}\end{aligned}$$

From this, the actual weight of any CW agent to be destroyed can be calculated by applying Formula (IV):

$$\begin{aligned}W_{des}(CWA_1) &= 90 \text{ tons} && \text{(for Country A)} \\ W_{des}(CWA_2) &= 22.5 \text{ tons} && \text{(for Country A)} \\ W_{des}(CWA_2) &= 25 \text{ tons} && \text{(for Country B)} \\ W_{des}(CWA_3) &= 50 \text{ tons} && \text{(for Country B)}\end{aligned}$$

These results show that if Country A wishes to destroy its CWA_2 stockpile first, it need only destroy 22.5 tons in that phase. However, if CWA_1 is chosen instead, it must destroy 90 tons, that is, four times as much as CWA_2 , because the TI of CWA_1 is only a quarter of that of CWA_2 .

The results also show that if countries A and B both destroy CWA_2 first, even though the tonnages of their total stockpiles and of CWA_2 are equal, the actual weights of CWA_2 to be destroyed by the two sides are not the same owing to the inequality of their actual CW capabilities, as indicated by their SEs.

The above illustrates that by using the SE concept it is easy to determine how many tons of a CW agent a State should destroy in a given phase of destruction.

5. Discussion and Conclusion

(a) The concept of Stockpiled Equivalent of chemical warfare agents can truly reflect the CW capabilities of States. It may, therefore, serve as an appropriate basis for balanced destruction of CW stockpiles.

(b) The formulae in this paper are applicable to any lethal or harmful CW agent.

(c) The present formulae are also applicable to binary weapons, in which case certain key precursors would be involved. Hence, when calculating the Stockpiled Equivalent or Destruction Quantity of a key precursor, the formulae in this paper should be used together with the relevant chemical equations by which the end-product (i.e. a CW agent) is formed from the precursor.

(d) If the diversion of some CW agents for peaceful purposes is allowed as a means of elimination of CW stockpiles under the future Convention, the formula for Destruction Quantity will be the formula for diversion quantity as well.

(e) In view of the purity change of the stockpiled CW agents, a purity percentage "P" may be added to Formula (III), which becomes

$$SE = P \cdot W \cdot TI$$

(f) The present concept and formulae, being of a purely technical and neutral nature, give no preference to any proposed order of destruction. Furthermore, by this concept the States concerned would be free to choose in the light of their specific conditions their own order of destruction without endangering the existing balance of forces between them.

CONFERENCE ON DISARMAMENT

CD/6061/
4 July 1985

Original: ENGLISH

LETTER DATED 2 JULY 1985 FROM THE
PERMANENT REPRESENTATIVE OF CANADA TRANSMITTING
A TWO VOLUME COMPENDIUM OF CD VERBATIM RECORDS
AND WORKING PAPERS SUBMITTED TO THE CONFERENCE ON THE
SUBJECT OF THE PREVENTION OF AN ARMS RACE IN OUTER SPACE

I refer to my 2 July 1985 statement before the Conference on Disarmament in which I announced that I would be providing the Secretariat with copies of a two volume compendium of CD verbatim records and working papers submitted to the Conference on the subject of the prevention of an arms race in outer space.

I am pleased to confirm that arrangements have been made for the delivery of 41 copies of the compendium to your documentation office. I would be grateful if you could ensure that a copy is distributed to each member delegation of the Conference on Disarmament.

Signed: J. Alan Beesley
Ambassador and Permanent
Representative

1/ A limited distribution of this compendium in English only has been made to the members of the Conference on Disarmament. Additional copies are available from the Permanent Mission of Canada at Geneva.

GE.85-62106

PREVENTION OF AN ARMS RACE IN OUTER SPACE

Working Paper of a group of socialist countries

1. The world has recently come to an extremely dangerous frontier: the arms race, which has reached unprecedented dimensions, is not only intensifying but also threatening to spread to outer space. The danger that space will become the springboard for aggression and war is increasingly real. Programmes are being carried out to develop space weapons that are intended to destroy objects in space and attack targets on Earth from space. These activities, which stem from calculations on achieving military superiority, are likely to make an arms race in space irreversible and seriously destabilize the situation, and they heighten the threat of nuclear war. The onset of an arms race in outer space will undermine the prospects for arms limitation and reduction as a whole. The militarization of space, if it cannot be halted, will swallow up enormous material and intellectual resources, thereby doing great damage to the peaceful development of mankind and the solution of pressing global problems, and create insurmountable obstacles to international co-operation in the peaceful use of outer space.
2. It is necessary to prevent this fatal course of events, and not to allow space to be turned into a source of military danger. The exclusion of space from the sphere of the arms race must be a strict norm in the policy of States, and a universally recognized international obligation.
3. The socialist States consider that strike weapons of any kind - conventional, nuclear, laser, particle-beam or any other form - whether in manned or unmanned systems should not be introduced into or stationed in space. Space weapons should not be developed, tested or deployed either for anti-missile defence, or as anti-satellite systems, or for use against targets on Earth or in the air. Such systems which have already been developed should be destroyed. In other words, the socialist States propose that agreement should be reached on the prohibition and elimination of an entire class of weapons, namely, attack space systems, including space-based anti-missile systems and anti-satellite systems.

4. Strict compliance with the indefinite 1972 Treaty on the Limitation of Anti-Ballistic-Missile Systems between the USSR and the United States is of particular significance for the prevention of the militarization of space.

The socialist States attach great importance to the absolute and strict implementation of multilateral agreements limiting the use of space for military purposes. These include the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies of 1967, and the Treaty banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water of 1963.

5. Given present developments, urgent measures must be taken to prevent an arms race in outer space. These measures may be worked out and adopted through both bilateral and multilateral negotiations. The socialist States consider that bilateral and multilateral negotiations complement each other.

6. The socialist States express satisfaction at the fact that the Conference on Disarmament was able to take the decision to set up an ad hoc committee on item 5 of its agenda, "Prevention of an arms race in outer space". They are ready to co-operate with the other States members in the implementation of the Ad Hoc Committee's mandate.

7. In the view of the socialist States, in carrying out its mandate the ad hoc committee should as a first step at this stage concentrate on examining the following issues:

(a) Political, military, economic and other consequences of the extension of the arms race into outer space.

(b) Significance of existing international agreements relating to the limitation of military activity in outer space for the prevention of an arms race in space.

(c) Proposals by States members of the Conference on Disarmament on the prevention of an arms race in outer space. Under this point, consideration should be given in particular to the proposals of the USSR on the conclusion of a treaty on the prohibition of the stationing of weapons of any kind in outer space (1981), the conclusion of a treaty on the prohibition of the use of force in outer space and from space against the Earth (1983) and on the use of outer space exclusively for peaceful purposes for the benefit of mankind.

8. The socialist States express the hope that the successful fulfilment of its mandate by the Ad Hoc Committee on the Prevention of an Arms Race in Outer Space will enable the Conference on Disarmament rapidly to embark upon negotiations on the conclusion of an agreement or agreements, as appropriate, for the prevention of an arms race in outer space in all its aspects, as it was recommended to do by the United Nations General Assembly. Only the guaranteed prevention of the militarization of space will make it possible to use space for creative rather than destructive purposes, and open the way for uniting the efforts of all States for the peaceful use of outer space.

CONFERENCE ON DISARMAMENT

CD/608
8 July 1985

ENGLISH
Original: FRENCH

PREVENTION OF NUCLEAR WAR, INCLUDING ALL RELATED MATTERS

Working paper submitted by Romania

Romania attaches particular importance to the prevention of nuclear war, including all related matters.

The arms race, particularly the nuclear-arms race, has escalated to record dimensions, increasing the danger of a nuclear disaster which would destroy the attainments of our civilization and even the necessary conditions for the existence of life on our planet.

The deployment of United States intermediate-range nuclear missiles and the adoption of Soviet nuclear countermeasures have created an extremely dangerous situation in Europe.

Given the circumstances, in particular the vast quantities of nuclear weapons stockpiled in the world which could destroy the planet several times over, we consider that the number one problem of our time is to halt the nuclear-arms race first of all, embark on disarmament, avert the danger of a new world war and establish peace in the world.

The agreement reached on talks in Geneva on the problems of nuclear weapons and the prohibition of the militarization of outer space was welcomed by Romania as a major step towards the reduction of international tension. However, the agreement and the beginning of negotiations do not mean that the problems have been solved. Romania expects the declarations to be succeeded by genuine, sincere negotiations undertaken with a profound sense of responsibility, which would lead to appropriate agreements in keeping with the hopes of the world's peoples and to the cessation of the arms race, primarily the nuclear-arms race, the first steps in their reduction, until their complete elimination, and the prohibition of the militarization of outer space.

The results of these negotiations, which we would like to see attain their fixed objective, namely, the "complete elimination of nuclear arms everywhere", can make a significant contribution to the prevention of the risk of nuclear war.

It should also be stressed that in Romania's opinion, side-by-side with the bilateral talks, to which other States should also be able to make an

appropriate contribution, multilateral negotiations should begin immediately in the Conference on Disarmament on the subject of the prevention of nuclear war.

Multilateral and bilateral negotiations must be mutually complementary, the efforts and results of each having a positive impact on progress in the other. On the basis of this position of principle, the Romanian delegation has, ever since this item was included in the agenda, constantly called for practical negotiations to begin within an appropriate subsidiary body in order to identify and adopt appropriate practical measures to prevent the risk of nuclear war.

1. Since the inclusion in Conference's agenda of the item "Prevention of nuclear war, including all related matters", many views have been advanced on the approach towards and content of this agenda item, including in several Working Papers, inter alia, CD/341 of 4 February 1983; CD/355 of 21 March 1983; CD/357 of 28 March 1983; CD/406 of 4 August 1983; CD/411 of 11 August 1983; CD/484 of 4 April 1984; and CD/515 of 11 July 1984.

All these views contain interesting ideas which deserve serious and thorough examination by the Conference in order to identify appropriate steps that could be the subject of negotiations with a view to the adoption of measures to prevent nuclear war as well, as the use of force in general and the threat of use of force.

2. In order to consider these proposals, the Conference should establish without delay an appropriate subsidiary body to examine all proposals concerning this agenda item, in other words concerning the adoption of practical measures for the prevention of nuclear war.

The Romanian delegation is ready to display the necessary flexibility, for we believe that in view of the complexity of this subject any approach must necessarily be gradual, leading from the simple to the complex, and beginning with the identification of the main topics which should be covered by the negotiations.

In our opinion, the adoption of a programme of work in the form of a list of discussion topics, as suggested by several delegations, could facilitate our negotiations.

3. In order to contribute to the drawing up of such a list, the Romanian delegation wishes to put forward, on an indicative basis, some ideas on topics structured in the following manner:

- (i) The prevention of nuclear war in the general context of all problems relating to international security, the relationship between disarmament, the democratization of international relations, the elimination of underdevelopment and efforts to build a new international order:

The interrelationship between political, economic, military, legal and other factors.

- (ii) Political and legal measures to strengthen and develop security at the world level (United Nations) and at the regional level (Conference on Security and Co-operation in Europe, other regional systems):
- Prohibition of the use or threat of use of force;
 - Undertakings by all States to settle their disputes peacefully;
 - Other measures to strengthen international peace and security.
- (iii) Measures to increase confidence among States and to create the necessary climate for the resumption of disarmament negotiations:
- Notification concerning military manoeuvres, sending of observers, improved information, communications and consultations among States and the adoption of other specific measures to enhance confidence among States on a regional and world-wide basis;
 - Adoption of concrete measures to prevent accidental nuclear war, by the extension of the existing bilateral arrangements to other nuclear-weapon States and the preparation of a multilateral agreement on this subject;
 - Discontinuance of all deployment or replacement of nuclear weapons, and of other actions to stockpile new means of mass destruction, including the discontinuance of actions aimed at the militarization of space during the bilateral negotiations between the Soviet Union and the United States in Geneva;
 - Freezing of military expenditures at the 1985 level and their gradual reduction, beginning with an initial 10 per cent cut in current expenditures.
- (iv) Measures aimed at halting the nuclear arms race:
- Freezing of existing nuclear arsenals, as an interim measure that is part of a nuclear disarmament process rather than a means of preserving the status quo;
 - Discontinuance of research, development and testing of new weapons, primarily nuclear weapons, and their delivery systems. In this category of measures, the halting of nuclear testing is of primary importance;
 - Prohibition of the militarization of outer space.
- (v) Measures to limit and reduce the use of nuclear weapons:
- Prohibition on the first-use of nuclear weapons, by unilateral declarations or the preparation of a multilateral agreement;
 - Adoption of effective international arrangements to guarantee non-nuclear-weapon States against the use or threat of use of nuclear weapons and of force in general;

Negotiation and conclusion of an international convention prohibiting the use of nuclear weapons;

Creation of nuclear disengagement zones and nuclear-weapon-free zones in various parts of the world, such as the Balkans.

- (vi) Practical measures to be negotiated with a view to the gradual reduction and complete elimination of stockpiles of nuclear weapons, including the discontinuance of production of fissionable material for military purposes and the diversion of nuclear material to peaceful uses. This stage could culminate in the preparation of a multilateral agreement for the discontinuance of the production, development, storing and transfer of nuclear weapons as the final measure for outlawing nuclear weapons and averting all danger of nuclear war in the only completely reliable manner.

4. The final objective of the Conference's activity should be, as stressed in General Assembly resolution 39/148 P and the draft mandate proposed by the Group of 21 in CD/341, to undertake negotiations with a view to achieving agreement on appropriate and practical measures for the prevention of nuclear war. In order to contribute to attaining this final objective, the Conference should this year set down its results in a report which could have three distinct parts:

A part briefly summarizing the exchange of views in the ad hoc Committee;

A description of the various measures of a political and legal nature which could, in the opinion of States members of the Conference on Disarmament, be examined within the United Nations or in other forums, with a view to the adoption of practical measures for the prevention of nuclear war.

Identification of practical measures on which the Conference on Disarmament should begin negotiations.

CONFERENCE ON DISARMAMENT

CD/609

8 July 1985

ENGLISH

Original: SPANISH/ENGLISH

LETTER DATED 8 JULY 1985 FROM THE PERMANENT REPRESENTATIVE OF MEXICO ADDRESSED TO THE PRESIDENT OF THE CONFERENCE ON DISARMAMENT TRANSMITTING THE TEXT OF THE STATEMENT ADOPTED BY THE SYMPOSIUM ON "SURVIVAL IN THE NUCLEAR AGE" HELD IN NEW YORK ON 25 AND 26 APRIL 1985

I have the honour to transmit herewith the text of the Statement adopted by the Symposium on "Survival in the nuclear age" held in New York on 25 and 26 April 1985, under the sponsorship of the Third World Foundation for Social and Economic Studies and Parliamentarians for World Order.

Since the Statement deals with topics which are intimately related with those included in the agenda of the Conference on Disarmament, I should be grateful if you would kindly arrange to have the text of the Statement circulated as an official document of the Conference.

(Signed)

Alfonso García Robles
Ambassador
Permanent Representative of Mexico
to the Conference on Disarmament

STATEMENT

OF THE SYMPOSIUM ON "SURVIVAL IN THE NUCLEAR AGE" HELD UNDER THE
SPONSORSHIP OF THE THIRD WORLD FOUNDATION FOR SOCIAL AND
ECONOMIC STUDIES AND PARLIAMENTARIANS FOR WORLD ORDER

(New York 25-26 April 1985)

Forty years ago this week the nations of the world, united by their struggle against a common enemy, and with memories fresh of the terrible conflict, convened with the resolve to save succeeding generations from the scourge of war. Since then, in the nuclear age that followed, those hopes have faded, and our generation now faces a challenge to survival.

Gathered here at the United Nations, coming from East and West, North and South, we 29 participants are in full agreement that we must rekindle the hopes of San Francisco and recapture the spirit of cooperation that inspired the Charter. In our discussions we considered the problems of survival in the nuclear age and the security and well-being of humanity. Our reflections and conclusions are set out below.

The Nuclear Threat

The escalation of the nuclear arms race arises in the main from political competition and increasing mistrust and lack of confidence between the two major alliances, and from the destabilizing effects of the rapidly advancing technology of nuclear weapons and their delivery systems. These developments have increased tension in international relations and heightened the risk of nuclear war. They have resulted in the build up of 50,000 nuclear warheads.

The use of a fraction of existing arsenals of nuclear weapons could bring about catastrophic consequences for the global environment and the ecological balance; it could induce around our planet a nuclear winter which would be fatal for all including the attacker even without any retaliation, it would wreak devastation on belligerents and non-belligerents alike, and result in the destruction of civilization and jeopardize the very survival of humankind. We have reached the stage where a vast and increasing number of people the world over have come to recognize that any use of nuclear weapons is contrary to human conscience and reason, a crime against humanity, a violation of the foremost human right -- the right to live. Mankind has not only a common interest in wanting to survive, it has a moral obligation to do so.

Yet negotiations on arms limitation and disarmament issues are lagging far behind the technological development of new weapons systems of greater accuracy, range, versatility and destructive power. Also, qualitative improvements create weapon systems which become increasingly difficult to verify. If any side, in search

of military advantage, develops and deploys strategic weapons that suggest an attempt to reach for a first strike capability, the other side inevitably responds. The escalation is unending; the risk of the outbreak of nuclear war becomes more likely causing greater insecurity and instability in all aspects of international relations.

Any attempt to gain military superiority, or acquire capabilities "to fight and win nuclear wars" is not only illusory, but it undermines security for all.

East West Relations

Just as the arms race is sustained by and fuels East-West tensions, so disarmament cannot be achieved save in the context of diminishing tension. While general and complete disarmament must remain the ultimate goal of all our efforts, human survival in the nuclear age imposes on the nuclear powers an immediate duty to move toward the elimination of nuclear arms. But it also makes it imperative that they exercise moderation and restraint in their mutual relations. Restraint in relations between nations must become a way of life. If it does, the arms race will lose its stimulus and disarmament its obstacles.

While the main burden of reaching agreement on disarmament must rest with the two major powers and their allies, we believe that important roles exist for all countries and for all people - including those of the developing world whose development is a victim of the arms race and whose survival is as endangered as all other nations. Most specially, we see the need for coalitions of countries and groups - including even aligned countries - that can together enlarge their influence with the main nuclear powers to ensure human survival in the nuclear age. We are confident that in the end the collective voice of most of the world's people and governments can encourage the super powers to end the threat of an all-destroying world conflict. But those voices cannot be heard unless they are raised. We encourage them all to do so now before there are none to speak and none to listen.

Freeze

There is an urgent need to stop the nuclear arms race, and thereafter to achieve important qualitative limitations and substantial quantitative reductions of nuclear arms leading to their eventual total elimination. If nuclear arms are to be effectively and meaningfully reduced there must first be a mutual and verifiable freeze on testing, production and deployment of all nuclear weapons and their delivery systems, along with a cut-off in the production of fissionable materials for weapons purposes. Such a freeze would raise the level of trust among states, ease international tension and create a favourable atmosphere for drastic reductions of nuclear arsenals. This process could be initiated by either unilateral declarations or a joint declaration by the two **super-Powers**.

In the past, lack of consensus about the adequacy of verification of compliance with arms limitation measures has often prevented agreement. Present and potential verification capabilities are more than adequate to ensure that significant violations of the measures urged in this Statement cannot remain undetected.

Comprehensive Test Ban

The prohibition of nuclear weapon tests in all environments by all states for all time has been the insistent demand of the international community for the last 25 years. No other disarmament issue has been pursued so persistently and for so long. A comprehensive test ban is crucial for the success of efforts to halt and reverse the nuclear arms race and to prevent the expansion of existing arsenals and the spread of nuclear weapons to additional countries. Despite the considerable progress made towards the conclusion of a comprehensive test ban treaty and the undertakings given by the three principal nuclear weapons powers in the 1963 Partial Test Ban Treaty and the 1968 Non-Proliferation Treaty, no treaty was achieved. It is now widely recognized that existing means of verification and those agreed to in the trilateral negotiations of 1977-80 are quite adequate to ensure compliance with a comprehensive test ban. All that is required is the necessary political will and a decision to conclude a comprehensive test ban treaty.

No-First Use

The solemn declaration made by two nuclear weapon states not to be the first to use nuclear weapons is an important contribution to decreasing the danger of nuclear war. We urge the other three nuclear weapon states to assume a similar obligation not to be the first to use nuclear weapons. This would be tantamount to banning the use of nuclear weapons not only against all non-nuclear weapon states, but indeed against all states.

Outer Space

Outer space is a "common heritage of mankind". It is in the common interest that the exploration and use of outer space should be solely for peaceful purposes, that the arms race should not be extended there, and that outer space should not become a battle-ground of the future. Strategic defence initiatives relating to ballistic missile defence systems, under research and development, and anti-satellite systems, raise the serious possibility of militarization of outer space and a dangerous escalation of the nuclear arms race. They also threaten the viability of several existing arms limitation agreements. They introduce an altogether new element which is dangerous and destabilizing and might actually provoke the use of nuclear weapons by either side. Instead of rendering nuclear weapons obsolete, it is more likely to result in a redoubled arms race in both defensive and offensive weapons.

These developments offer no substantial defence against strategic ballistic missiles, and do not limit the effectiveness of other systems - such as bomber aircraft and cruise missiles. At today's levels of super power deployment - about 10,000 strategic warheads on each side - even a miraculous 95 per cent protection level would be insufficient to save either society from utter destruction in the event of general nuclear war. Any effort in research or testing will inevitably lead to a

reciprocal effort by the other side, and so each side will move to more offensive systems, of submarine launched missiles, cruise missiles, and advanced technology aircraft and missiles in order to overwhelm or evade the defence.

The collective weight of world scientific opinion rejects a "Star Wars" programme as an exercise in futility. In an environment of tension and insecurity, it is a highly dangerous and wasteful investment in delusion. There is no technical salvation from the threat of nuclear war. Only political solutions leading to the elimination of nuclear weapons can avert the danger.

All nations should, therefore, agree on a ban on all testing and deployment in outer space of any outer space-based weapon for the destruction of objects on the earth, in the atmosphere or in outer space; and of any ground based weapon for the destruction of objects in outer space.

Non-Proliferation

1985 will see the third review of the Non-Proliferation Treaty. The failure by nuclear weapon states during the last 15 years to fulfil their obligation under the NPT relating to the cessation of the nuclear arms race, and the continuation of vertical proliferation of nuclear weapons increases the danger of horizontal proliferation and endangers the entire non-proliferation régime. There is need for concrete and meaningful action now if the Non-Proliferation Treaty - which we emphasize is a most important international agreement - is not to become yet another victim of the arms race.

Disarmament and Development

There exists a dynamic triangular relationship between disarmament, development and security. So long as the arms race, and particularly the nuclear arms race, continues, the world will fail to achieve a more stable and balanced social and economic development within a more sustainable international economic and political order, as well as global and national security. The armaments competition - quantitative and qualitative, conventional and nuclear - has had severely damaging economic and social implications for the peoples of all nations - rich as well as poor. Even a fraction of the precious resources currently wasted in excessive military expenditures, if diverted to social and economic development and especially for the reduction of poverty of two-thirds of the world's population, would vastly improve life and security on our planet. The increasingly enormous military expenditure has been detrimental to their economies by causing distortions and imbalances, and has contributed to the current worsening of the international economic situation. There is the further disturbing implication of the spreading of the military culture to the developing countries. The failure to bring the arms race under control has led to deepening confrontation and distrust, and a preoccupation with security has had adverse consequences not only for East-West detente, but also for North-South co-operation. Governments should plan for and prepare a process of conversion of resources from military to constructive civilian use. Not least, such steps would increase confidence in the sincerity of their desire to reach genuine disarmament measures.

Six Heads of Government Peace Initiative

The declaration of the six Heads of Government, of 22 May 1984 renewed in the New Delhi Declaration of 28 January 1985, urged the nuclear powers to abide by the voice of reason. The Declaration welcomed the bilateral negotiations between the Soviet Union and the United States on "a complex of questions concerning space and nuclear arms ... with all the questions considered and resolved in their inter-relationship". They endorsed the aim of preventing an arms race in space and achieving substantial reductions of the existing nuclear arsenals and ultimately eliminating nuclear arms everywhere. That Declaration reflects the sentiments of billions of people throughout the world. These sentiments are rooted in their intuitive understanding that the common security of everyone on this planet is essential to the survival of anyone in the nuclear age.

Public Opinion

The lack of political will by governments to halt and reverse the nuclear arms race has in large part been due to the absence of sufficient knowledge and understanding by the public of the nature and consequences of the arms race. It is necessary to inform and mobilize public opinion if meaningful progress is to be made.

Proposed Action

Meeting here on the occasion of the Award of the Third World Prize to Willy Brandt, we join him in the call he has made on the major nuclear powers to agree "on rules which make World War III impossible". We wholly agree with him that it is "unacceptable and terrifying" that the people of the world must "depend in their right to live on a small group of people in one or two capitals", a situation now created by the irrational arms race.

To this end, we call for the rapid initiation and implementation of a programme on disarmament, which includes the measures listed below on which action is most urgently required:

1. an agreement to prevent the militarization of and the extension of the arms race to outer space;
2. the immediate cessation of all tests of nuclear weapons and the prompt conclusion of a comprehensive test ban treaty;
3. a mutual and verifiable freeze on the testing, production, and deployment of nuclear weapons and their delivery systems;
4. a declaration by those nuclear weapon states that have not done so, not to be the first to use nuclear weapons.

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UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

SEISMIC MONITORING FOR A COMPREHENSIVE NUCLEAR TEST BAN

Corrigendum

page 2, paragraph 10(b):

The first sentence should be amended to read:

Secondary (s) transverse body waves with a propagation speed of about 0.6 times the speed of the corresponding P wave.

page 12, paragraph 40, line 12:

Replace "justify" with "rectify".

CONFERENCE ON DISARMAMENT

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UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

SEISMIC MONITORING FOR A COMPREHENSIVE NUCLEAR TEST BAN

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SUMMARY

The Working Paper sets out United Kingdom views on the subject of seismic monitoring for a comprehensive nuclear test ban.

The first eight paragraphs contain historical background, and outline the objectives of forensic seismology.

Paragraphs 9-22 on the subject of Detection deal with the problems of long-range monitoring of underground nuclear explosions, discussing inter alia the instrumentation available and detection thresholds.

Paragraphs 23-38 on Identification deal with the problem of differentiating between seismic signals due to explosions and earthquakes.

Paragraphs 39-47 discuss the problem of Evasion, including the technical factors and other considerations that have to be taken into account.

Paragraphs 48-55 on Developments in Detection and Identification Capabilities consider the question of whether the detection and identification capabilities of seismic monitoring could be made adequate for the purposes of a test ban.

Paragraph 56 discusses the possibility of establishing a Global Monitoring Network and its likely capabilities.

Paragraphs 57 and 58 offer conclusions that may be drawn from the analysis in the paper.

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SEISMIC MONITORING FOR A COMPREHENSIVE NUCLEAR TEST BAN

HISTORICAL BACKGROUND

1. The Conference of Experts, which met in Geneva in 1958, to study methods of detecting violations of a possible agreement on the suspension of nuclear tests, recognized that seismological methods offered the only practical long range means of monitoring compliance with a treaty banning underground nuclear weapon test explosions. The Experts concluded, on the basis of data then available, that a worldwide network of 180 seismic control posts would be required to monitor tests in all environments. Their conclusion rested on a large data bank of seismic signals from earthquakes, a moderate amount of information on the signals from mostly relatively small chemical explosions, and the seismic measurements made on just one underground nuclear explosion. The available theories on the generation of seismic waves by earthquakes and explosions were rudimentary.

2. The Governments of the United States, the Soviet Union and the United Kingdom accepted the report by the Experts and in November, 1958, convened a Conference to discuss a treaty to prohibit all nuclear weapon test explosions, i.e. a comprehensive test ban treaty. Meanwhile, the United States had conducted further underground nuclear test explosions. In the view of Western delegates, the seismic data from these tests invalidated some of the assessments previously made at the Experts Conference - but the Soviet delegation disagreed. Discussion failed to bridge the technical gap and for this and other non-technical reasons the attempt to negotiate a comprehensive treaty at that time was abandoned.

3. In the following years, a Partial (or Limited) Test Ban Treaty prohibiting nuclear explosions in space, in the atmosphere and in the oceans came into force in 1963; and the United States and the Soviet Union agreed on a Threshold Test Ban Treaty in 1974 and a Peaceful Nuclear Explosions Treaty in 1976. The monitoring problems relevant to these treaties are, however, not considered in this paper. In 1977 the United States, the Soviet Union and the United Kingdom began another attempt to negotiate a comprehensive test ban treaty and, although some progress was made, the negotiations were adjourned in 1980 without reaching a conclusion. Since that time, discussions relating to nuclear test bans have taken place at the Conference on Disarmament in Geneva.

4. The original Conference of Experts stimulated various countries to initiate vigorous research programmes aimed at investigating the application of seismology to the problem of monitoring a ban on underground nuclear weapon testing, i.e. forensic seismology. A report on progress was published by the United Kingdom Atomic Energy Authority in 1965. This paper is intended to summarize subsequent developments.

THE OBJECTIVES OF FORENSIC SEISMOLOGY

5. There are two main problems to be solved before seismic means can be adequate for monitoring a treaty banning underground nuclear weapon test explosions. First, there is the problem of detecting seismic signals from underground nuclear explosions against the ambient background of seismic noise; and second, of discriminating between signals from explosions and earthquakes. These questions of detection and identification are fundamental to forensic seismology. In addition, there is monitoring interest in the accuracy with which it is possible to determine the location (i.e. the epicentre) the origin time and the magnitude of seismic sources.

6. It is vital not only to establish the detection and identification performances that can be achieved by seismic means and to seek to improve them, but also to develop systems which would allow them to be realized under what may be termed operational conditions. Equipment, procedures and processes which are satisfactory under experimental conditions have to be made suitable for full-time deployment in the field, where environmental conditions may be severe; operating staff may be less well qualified; and requirements will exist for the timely transmission of reliable data to analysis centres. In other words, seismic system development work is also needed before an effective operational monitoring network could be created.

7. There are other problems relevant to underground test-ban monitoring which cannot be addressed in a seismic research programme. For example, forensic seismology cannot differentiate between a nuclear weapon test explosion and a nuclear explosion for peaceful purposes. Forensic seismology also cannot distinguish between underground nuclear and conventional explosions for which other arrangements would have to be found. These problems will not be considered further in this paper.

8. It should be noted that this paper does not deal either with the problems of on-site inspection which would be needed to complement seismic monitoring or with questions relating to the monitoring of other than the underground environment.

DETECTION

Introduction

9. This section of the paper and the following section on Identification largely deals with the problems of long-range monitoring of underground nuclear explosions conducted under conditions of close-coupling (see para. 45) in hard rock. Monitoring at regional distances, i.e. at less than 1,000 km/s, is discussed in later sections.

Types of Seismic Waves

10. An underground disturbance, whether natural or man-made, may generate at long range some or all of the following wave types:

(a) Primary (P) longitudinal body waves with propagation speeds varying between about 5 and 8 km/s near the earth's surface to about 13 km/s in the earth's interior.

(b) Secondary (S) transverse body waves with a propagation speed of about 8.6 times the speed of the corresponding P wave. S waves are also referred to as Shear waves.

(c) Love (L) horizontally polarized transverse waves which propagate only near the surface of the earth. Their maximum speed is about 4.5 km/s.

(d) Rayleigh waves which are propagated by an energy transfer by particles executing retrograde elliptical motion in a vertical plane containing the direction of propagation. They travel near the earth's surface with a maximum speed of about 4 km/s.

Ambient Noise Background

11. The signals from an underground disturbance have to be detected against the ambient seismic noise background. The natural background (which is a mixture of seismic waves of all types) originates partly in the vicinity of the detection station because of the random influences of wind, industrial and domestic activity, thermal stresses, etc. and partly from remote sources, particularly the oceans. There is a large peak in the seismic noise spectrum at about 0.15 Hz so that it is usual to search for seismic signals in frequency bands on either side of this peak. For long-range detection, these bands are normally centred on about 1 Hz - the short-period (SP) band - and on about 0.05 Hz - the long-period (LP) band. The ratio of the signal amplitude to the average amplitude of the noise, i.e. the signal-to-noise ratio, within these bands is a critical factor in both the detection and identification of seismic signals.

12. When considering the detectability of signals generated by underground explosions, it is also relevant that the amplitude of the natural background noise may be increased by the fluctuations produced by earthquakes. Moderate and large earthquakes generate seismic signals which are well above the ambient noise level for tens of minutes and, in effect, increase the background level against which signals from explosions would have to be detected.

Seismic Wave Propagation

13. Before a detailed analysis can be made of a seismic disturbance its epicentre has to be determined. To do this using the well established and most reliable methods it is necessary to detect the direct P wave. (Detection of direct P is also required before several of the identification criteria can be applied.) Direct P is most easily detected in the SP band. The transmission paths of P waves through the earth from the source to a distant receiver are complex because of the structure of the earth. Some of the P wave energy is trapped between the earth's surface and the Mohorovicic (M) discontinuity and some penetrates the M discontinuity and is refracted through the mantle and perhaps also through the earth's core. As a result it is possible to define for P waves three reception zones around a seismic source. The first zone extends from 100 km to about 1,000 km or 10° (where the angular measure refers to the angle subtended by the line joining source and receiver at the earth's centre). In this zone the first arrival P waves from shallow disturbances travel essentially along the M discontinuity and are then refracted back to the surface. The next zone, which may be a shadow zone, is where the waves trapped above the M discontinuity have been very heavily attenuated and where the waves which have penetrated the M discontinuity have not been refracted sufficiently to be returned to the earth's surface. For the Western United States, the second zone stretches from about 1,000 to 2,000 km or from about 10° to 20° ; there is however little or no shadow zone for P waves generated in some earth structures, notably in shield and platform regions such as exist in much of the USSR. The third zone completes the coverage of the earth's surface to 180° . In this zone, the seismic waves return to the earth's surface after propagation through the deep mantle and, for ranges beyond about 90° , also the core. The boundaries between the zones are not sharp and they vary in different parts of the world according to the variations in the earth's structure. The amplitude of the direct P waves in the first zone decreases approximately as the inverse square or cube of distance depending on the region. Beyond the second zone, the signal amplitude first increases as the

third zone is entered; then decreases with increasing range out to at least 30°; and then decays very slowly to around 95°. The amplitude then decreases rapidly to a distance of about 105° and from this distance to 140° the P amplitude is very low due to the shadow cast by the earth's core.

14. As seismic waves spread out from the source the various wave types tend to separate because of their different speeds of propagation. In the first zone, however, the propagation distance is so short and the region through which the waves propagate is so heterogeneous that direct P is followed by a very complex wave train which is made up of waves of some or all the types described in paragraph 10. At long range and particularly between 30° and 90° the SP seismograms consist essentially of P waves only. Such seismograms, particularly those from explosions, are often very simple. This simplicity may assist interpretation but it could mislead by giving a false impression of the nature of the source.

Instrumentation

15. The background noise from natural and man-made sources sets the minimum detection levels for seismic signals. This level can, however, be degraded by the noise generated within the detection equipment, i.e. by thermal noise in the seismometer and the signal processing electronics. In practice, such internal noise is not significant in the types of seismometers and signal processing equipment now available. Indeed the instrumentation for seismology has improved markedly over the last two decades. Previously it was necessary to use six seismometers and associated signal processing channels to record fully a seismic signal. It was necessary to have three SP seismometers to record the vertical and two horizontal components of the ground motion in the high frequency part of the spectrum and a further three LP seismometers to cover the low frequency band. By 1965, reliable seismometers of adequate sensitivity were commercially available but, whereas the SP instruments were small, portable and robust, the LP instruments were bulky, difficult to set up and susceptible to changes in ambient temperature and pressure. Much effort has been put into developing smaller seismometers covering both the SP and LP bands, so called broad-band instruments. They are now available. The KS 36000 is being manufactured in the United States, where an improved instrument, the KS 44000, is under development. The United Kingdom is developing an instrument with a performance similar to that of KS 36000. In most cases, such new instruments are competent to handle the large dynamic range of teleseismic signals without overloading; they are also tailored to provide outputs which allow the large volume of data generated by a seismic detection station to be processed and transmitted in real time.

16. The reduced size of seismometers is of particular importance because it makes it much more practicable to install them in bore-holes to reduce the level of environmental noise. The United Kingdom instrument is being designed to fit into a bore-hole of 4.5 inches diameter and the KS 44000 is being developed so that its bore-hole does not have to be drilled to the same high tolerances that are demanded by the KS 36000.

17. Global seismic monitoring performance would be improved if it were possible to install seismometers on the sea-bed as part of a global network. Hitherto, the main difficulty has been to develop a means to reduce the large ambient noise encountered by sensors deployed directly on the ocean floor. The United States have experimented with a system in which the sensors are placed in deep bore-holes beneath the ocean floor. Significantly enhanced signal-to-noise ratios were measured, particularly for regional signals which are refracted by the oceanic lithosphere.

Detection Threshold

18. Using the modern instrumentation at land sites, it is now theoretically possible to detect at distances of 30°-90°, i.e. in the third zone, the P wave signals from most disturbances of body wave magnitude $m_b \geq 4$ or a little lower ± 1 at sites where the seismic noise level is low, i.e. at sites well away from sea coasts and human activity and where the seismometers can be emplaced in hard rock. Seismologists measure the magnitude m of a seismic signal on a logarithmic scale. For any particular station, the value of m for a given signal is calculated from:

$$m = \log_{10} (A/T) + B (\Delta \quad h) + C$$

where A = the amplitude of the particular seismic signal of interest

T = the period of the signal

B = a function of Δ , the angular distance between source and receiver, and h , the depth of the source below the earth's surface

C = a station correction term, empirically determined

A body wave magnitude for P waves, i.e. the magnitude of a compressional P waves which has travelled through the mantle, is indicated by m_b .

19. At a noisy site it is possible to improve detection performance either by sinking the seismometers about 100 metres in bore-holes or by the use of an array of seismometers; array seismometers can be installed in bore-holes. The main value of bore-hole installations is in isolating the seismometers from the effects of atmospheric disturbances and high frequency seismic noise generated by the wind. A great deal of work has been done on investigating the performance of seismometer arrays: i.e. a spread of seismometers over an area, with the outputs from the individual seismometers being electronically processed and combined to maximize the signal-to-noise ratio. The original hopes for arrays deployed over large areas, i.e. areas with dimensions of 100 km or more - have not been realized, primarily because signals showed a greater variation in amplitude and shape over the aperture of large arrays than had been expected. It follows that the use of large arrays does not promise to give a significantly lower detection threshold than that available with a single seismometer station at a seismically quiet site. Modest array stations, i.e. arrays with linear dimensions of up to 25 km, may, however, be useful at all sites for improving signal/noise ratios especially at sites which are less quiet so that performance becomes comparable with that at the best sites. In addition to lowering the background noise, arrays provide information on the speed and direction of propagation of signals which assists with the interpretation of seismic signals and makes an array more useful than single stations for treaty monitoring.

Magnitude/Yield Relationship

20. An assessment of the significance of a detection threshold of $m_b \geq 4$ in a test ban context requires a knowledge of the relationship between m_b and the yield of an

+/ NOTE This performance would be easier to achieve in the Northern Hemisphere than in the Southern Hemisphere because of the relative shortage of suitable land-based sites in the latter.

underground nuclear explosion which would produce a seismic wave of this magnitude. On the basis of data obtained from nuclear explosions conducted by the West, a threshold of $m_b 4$ can be equated to a nuclear explosion of about 1 kiloton occurring in a shield region with close coupling in hard rock. As will become clear later, the condition of close coupling in hard rock is important. If the medium in which the explosion is carried out is other than hard rock, the efficiency with which the explosive energy is converted into seismic waves is reduced. Thus for explosions carried out in dry alluvium, the conversion efficiency is only about one tenth of that for hard rock and hence, for this medium, $m_b 4$ equates to about 10 kilotons. The conversion efficiency can also be reduced by measures which de-couple the explosion from its geological surroundings; this possibility will be examined later.

21. Before leaving the question of detection performance, it must be noted that the yield/magnitude relationship has been empirically defined largely from data from Western underground nuclear explosions carried out at a relatively few sites, principally the Nevada Test Site (NTS). The NTS is in an earthquake zone and in an area with a highly attenuating upper mantle. There has been much discussion on whether the relationship established in such a zone applies to explosions at test sites in the USSR which are mainly in aseismic regions, i.e. regions free from earthquakes, and when the upper mantle structure is different from those at NTS; the debate has so far been inconclusive. There must also be uncertainty about conclusions relating to the detection and identification of explosions, which are based on data from explosions fired at a limited number of test sites and at depths judged to be sufficient to meet the containment requirements imposed by the Partial (or Limited) Test Ban Treaty. The consequences for explosions away from the currently used test sites and/or at depths significantly greater than that needed to ensure containment are to some extent unknown.

22. The magnitude of a disturbance is determined by averaging the magnitude estimates from a number of stations. The measured magnitude of a disturbance is subject to some uncertainty but if the number of stations contributing to the estimate is greater than say 10 the uncertainty in the magnitude may be rather small. However, the coupling between an explosion and the surrounding medium is variable so that the amplitude of the seismic waves generated by explosions of given yield is not constant. Thus even if the magnitude of an explosion can be determined accurately there will still be uncertainty in the yield estimate because of the uncertainty about the coupling. As already noted, for explosions in soft rock, i.e. dry unconsolidated material, the radiated signals may have amplitudes 10 times smaller than those radiated from explosions in what is usually referred to as hard rock; i.e. water saturated rock or consolidated and igneous rocks with little pore space. If an explosion generates a signal that is recorded at a number of stations with good signal-to-noise ratio and if the rock type were known the yield can be estimated to within an accuracy of about a factor of 2; i.e. if the best estimate of the yield of an explosion is Y , it is highly likely that the true yield lies between $Y/2$ and $2Y$.

IDENTIFICATION

Introduction

23. For test ban purposes, whenever a seismic signal is detected a decision has to be taken on whether it is due to an explosion or an earthquake. Recent research within the United Kingdom has shown that, worldwide, there are about 8,000 earthquakes

each year with a magnitude of $m_b 4$ or greater. Thus for test ban monitoring, there would be what amounts to about 8,000 "false" signals every year ^{o/} to be considered and rejected before there could be confidence that there had been no "true" signals, i.e. signals from explosions, in contravention of a Treaty. Unless there is some highly efficient means of identifying quickly almost all of the seismic signals generated by earthquakes, a test ban monitoring system would be rapidly overloaded and could not provide adequate confidence of Treaty compliance. Without such confidence there could be suspicions and accusations of violations to the detriment of international relations.

Original Discriminants

24. In 1958, there were really only three measures by which earthquakes might be identified, namely location, depth of focus and first motion. It was accepted that if a seismic signal were calculated to originate from a disturbance at sea, it could, in the absence of any hydroacoustic signal indicating the occurrence of an underwater explosion, be classified as an earthquake. The location or epicentre of a disturbance and its origin time can be calculated from the arrival times of signals from the disturbance at a number of widely spread seismic stations by the techniques customarily used by seismologists. The estimated location will be subject to both systematic and random errors and, in using location as a discriminant, this has to be allowed for by requiring an estimated epicentre to be at least say 25 km off a shore line before the disturbance should be classified as an earthquake. It will be noted from paragraph 18 above that the epicentre of disturbance has to be computed before it is possible to assign a seismic magnitude to it.

25. If the depth of a disturbance can be confidently determined to be greater than say, 10 km, it would be safe to conclude that the disturbance was an earthquake. Methods whereby depth might be measured have been investigated in detail. Attempts to estimate depth using travel times have been made by seeking to calibrate regions using earthquake signals originating at depths which have been estimated by other means. The results have not been encouraging. On the seismograms from some earthquakes it is possible to see clear pulses which are reflections of P and S waves from the earth's surface; these reflections being referred to as pP and sP respectively. The most reliable method of depth estimation is to use the arrival time difference between the direct P wave and the surface reflections. There is, however, a difficulty, particularly with low signal-to-noise ratio signals, of identifying the surface reflections in the seismogram. Theoretically a pP and sP wave identification can be checked by showing that the time difference between P and the reflections varies with distance as predicted from travel time tables; in practice this variation with distance is so small, particularly at long range, that the check is not very effective. Some confidence in pP identification can be obtained if it can be determined that the first arrivals of the P and pP waves are of opposite polarity, i.e. if the first P arrival is for an upward ground motion then the first pP arrival should have a downward motion and vice versa. The United Kingdom has developed signal processing methods to assist with polarity determination. Depth estimation, however, often cannot be made because the seismograms are so complex that it is not possible to pick out any possible surface reflections.

^{o/} NOTE There would be further "false" signals with magnitudes less than $m_b 4$.

26. The third of the original discriminants was "first motion". For an explosion, which should generate an outward pressure at the source in all directions, the first motion at all seismic stations distant from the source should be outwards. At long distance this means that the first ground movement due to an explosive source should always be in an upwards direction. On the other hand, an earthquake, which is the result of a sudden slip along a geological fault, should generate outward pressures in some directions and inward pressures in the others. Thus, if a number of seismic stations are located at long ranges around the epicentre of an earthquake, some should show upward first motions and some downward first motions. It was therefore suggested that, with a global network of seismic stations, if one or more recorded a downward first motion for a signal, that signal should be classified as to an earthquake. Later observations indicate that the first motion discriminant is not reliable. There have been examples of apparent downward first motions from explosions though whether or not these are due to the real first motion being obscured by noise or to errors in measurement or to some other cause is not known. There have been other examples of a failure to record any downward first motions from certain earthquakes. Whether or not these are due to the orientations of the geological faults at the location of the earthquakes relative to the geographical distribution of seismic stations at which they were recorded is also not known. At all events, the initial confidence placed in the reliability of the first motion criterion evaporated.

Signal Complexity and Spectral Ratios

27. In the 1960s, the United Kingdom investigated two other possible discriminants, signal complexity and spectral ratios. The signal complexity criterion was suggested by the observations up to that time that seismograms recorded at array stations from earthquakes at long range were often much more complex than those from explosions. Although relatively simple seismograms were sometimes recorded for earthquakes, it was believed that all complex ones were of earthquake origin and hence disturbances with complex seismograms could be discarded as earthquakes leaving only simple seismograms to be investigated further. Unfortunately as more observational data on explosions accumulated, it became clear that these too could give rise to complex seismograms. The complexity criterion therefore ceased to be a reliable discriminant and interest in it waned.

28. To apply the spectral ratio criterion, the ratio of the high (say 2-4 Hz) to the low (say $\frac{1}{2}$ -1 Hz) frequency energy in a P wave signal is determined. It was found that the signals from explosions in East Kazakhstan had, in general, relatively more high frequency energy than signals from earthquakes. However, when the spectral ratio was measured for signals from the Nevada Test Site, a similar difference was not found. It therefore seems that the spectral ratio criterion does not have universal application.

The $m_b : M_s$ Criterion

29. A breakthrough in identification occurred in the 1960s with the recognition that underground explosions are normally much less efficient than shallow earthquakes equivalent size in generating long period Rayleigh waves (see paragraph 10). Thus for an explosion and an earthquake which each have a short

period P wave magnitude of m_b , the value of M_s , ^{*/} the long period Rayleigh wave magnitude for the explosion, is likely to be significantly less than the value of M_s for the earthquake. If, for a large number of earthquake and explosion signals, the values of m_b and M_s for each disturbance are plotted on Cartesian co-ordinates (m_b along the x-axis and M_s along the y-axis), it will be found that almost all, if not all, the points representing earthquakes fall above a selected positively sloping line from low m_b and M_s values to high m_b and M_s values and almost all, if not all, points representing explosions fall below this line. In other words, the earthquakes and explosions separate out to form two spatially separated populations. The line separating these two populations can be fixed empirically. Then, the values of m_b and M_s for a disturbance of unknown origin can be plotted on the $m_b : M_s$ diagram and the disturbance can be classified as an earthquake or explosion depending on whether the $m_b : M_s$ point falls above or below the dividing line. This is the application of the so-called $m_b : M_s$ criterion.

30. The accuracy with which the dividing line between the earthquake and explosion populations can be determined depends on the statistics of the data points from known earthquakes and explosions. The efficiency of the application of the $m_b : M_s$ criterion for identification purposes depends on the uncertainty in the measurement of the values of m_b and M_s for the disturbance for which an identification is needed. Because of these uncertainties, the earthquake and explosion populations have to be divided not by a line but by a band with the width of the band being determined by the inaccuracies and by the level of assurance needed in avoiding a false identification. Thus an unknown disturbance would be classified as an earthquake, an explosion, or uncertain (ambiguous) depending on whether its $m_b : M_s$ value fell above, below or in the band.

31. It is obvious that the $m_b : M_s$ criterion can be applied efficiently only if there is an accurate estimate of both m_b and M_s for an unidentified disturbance. Sometimes there are difficulties in detecting the Rayleigh waves from disturbances for which a body wave magnitude can be determined from the P wave. This may be due simply to the low signal level of the Rayleigh wave relative to ambient noise or to the obscuration of the Rayleigh wave by the surface wave train from a large contemporary earthquake. For example, in one study of seismograms of earthquakes of magnitude m_b 4.75 and greater (equivalent to an explosion of about 5 kt close coupled in hard rock) it was found that the surface waves were obscured by signals from other earthquakes in 14 per cent of the cases. The problem with detecting and measuring Rayleigh waves from explosions is more severe because, for a given m_b their Rayleigh surface waves have lower amplitudes than those from earthquakes.

32. United Kingdom experience is that, in order to obtain sufficiently accurate estimates of m_b and M_s , the signal-to-noise ratio for the received signals needs to be about a factor of 3 higher than that needed purely for detection purposes. This means that, given a network that can detect down to m_b 4 (see para. 18), the identification, as opposed to the detection, threshold is about m_b 4.5 (assuming surface waves can be observed (see paragraphs 33 and 49)) corresponding to an explosion of about 3 kt close coupled in hard rock (or about 30 kt in a sufficiently thick stratum of dry alluvium).

^{*/} The notation used by seismologists can be confusing. Although Secondary or Shear-waves are referred to as S-waves, the subscript "s" is used in M_s , to denote the magnitude of a surface wave of the Rayleigh type.

Anomalous earthquakes

33. Unfortunately, the basis for the $m_b : M_s$ criterion does not hold good for all earthquakes. Some earthquakes have been recorded showing only relatively weak surface waves. These anomalous earthquakes have mostly occurred in South-Central USSR and Tibet; several have occurred in East Kazakhstan. There is some question about whether all the anomalous earthquakes have been correctly classified. In some cases, a United States re-estimation of the value of M_s , taking account of the thickness of the crust under the Tibetan plateau, has led to $m_b : M_s$ values consistent with the criterion. Other cases, however, have remained in the anomalous category and these will be considered later.

Reservations about the $m_b : M_s$ criterion

34. Some reservations about the general effectiveness of the $m_b : M_s$ criterion remain because it has been possible to test it against explosion signals from very few areas. It is noted, for example, that in an $m_b : M_s$ diagram, the population of explosions at the Soviet test site in E. Kazakhstan is well separated from that for the population of Soviet earthquakes, whereas, for explosions at the American test site in Nevada, the separation is small. The reason for this difference seems to lie in the fact that the test sites in E. Kazakhstan and Nevada are in seismically inactive and active regions respectively and this implies that the regions have different underlying geologic structures. It appears that the structure under E. Kazakhstan results in less attenuation in the P waves than is found for Nevada. Consequently the m_b to M_s ratio for a test of a given yield in E. Kazakhstan is greater than the ratio for the same yield fired in Nevada and the point on the $m_b : M_s$ diagram for the E. Kazakhstan test will fall further away from the earthquake population than the equivalent point for Nevada. Nevertheless, the Nevada data indicate that the $m_b : M_s$ criterion is satisfactory at this site and it is noted that for explosions in the Aleutian Islands (a seismically active region), the separation between explosions and earthquakes on the $m_b : M_s$ diagram is larger than for any other test site. With this conflict of evidence, the present reservations about the $m_b : M_s$ criterion will probably be dispelled - or justified - only when it is possible to understand more clearly why explosions and earthquakes normally separate out on the $m_b : M_s$ diagram; how to correct m_b for differences in the geologic structures beneath the site of an underground explosion; and how surface waves are generated.

35. There is continuing speculation about whether the $m_b : M_s$ criterion would hold good if disturbances of lower magnitude than at present could be measured. The question is whether, at these lower magnitudes, the explosion and earthquake populations overlap. Theoretical arguments have been adduced both for and against an overlap. Some observations initially indicated that the two populations did indeed overlap; later examination has indicated that the overlap may be attributed to a bias in the estimation of the magnitudes. For the moment, the question remains in doubt. The applicability of the $m_b : M_s$ criterion to low magnitude disturbances will also depend on how frequently anomalous earthquakes at low magnitudes occur.

Seismogram modelling

36. Attempts are being made to understand why "anomalous" earthquakes cannot be correctly identified as earthquakes using the $m_b : M_s$ criterion and to develop methods for their identification. Experience shows that many of these earthquakes each produce SP P-wave seismograms that are comparatively simple showing between one and three pulses and little else. The simplest interpretation of these pulses is that they are P and the surface reflections from an earthquake at a depth of 20-30 km.

To confirm that the seismograms are from an earthquake and not a series of explosions, techniques have been developed to test whether the amplitude, polarity and arrival times of the pulses are compatible with the most widely accepted model of the earthquake source; the aim of the studies being to determine sufficient details of the earthquake source to allow the observed seismograms to be modelled. Where it has been possible to apply these techniques, i.e. when there are an adequate number of seismic records at good signal/noise ratios, it has been shown conclusively that the disturbances are indeed earthquakes. The technique now needs to be applied to many more earthquakes before the full value of the method can be assessed.

37. These techniques for identifying anomalous earthquakes would probably fail if the earthquake occurred at depths similar to that at which explosions are fired. How commonly anomalous earthquakes occur at such shallow depths is not known. So far none appear to have been reported.

38. Modelling work has also been done for explosions. For a long time it has been possible to model seismograms recorded at long range to predict the general form of many P wave signals. Accounting for the detailed shape of the seismograms recorded at long range is, however, proving very difficult even when the source structure and the depth of firing are accurately known. There is no validated theory to account for the generation of the shear, i.e. Secondary and Love, waves which are frequently found in seismograms from explosions. Part of the difficulty may arise because explosive sources are near the earth's surface so that spalling and fracturing distorts the explosion signal. This might be checked if more explosions were carried out at much greater depths than those required merely to contain the explosion debris.

EVASION

Introduction.

39. Before considering the more recent work on detection and identification, it is relevant to discuss the problem of evasion, i.e. the vulnerability of a test ban monitoring system to deliberately engineered measures which would significantly degrade its effectiveness. The detection and identification threshold for a seismic monitoring system are specified in terms of seismic magnitudes but the adequacy of the system for test ban monitoring purposes needs to be judged against its capability to detect and identify explosions quantified in terms of nuclear yield. As has already been pointed out in paragraph 20 the relation between seismic magnitude and yield depends on the nature of the medium in which the test explosion is carried out; the seismic magnitude of an explosion of given yield can vary by up to a factor of about 10 depending on the characteristics of the medium in which it is fired. This variability exists for explosions closely coupled to the surrounding medium and needs to be taken into account when assessing verification adequacy. Perhaps, more significantly, this variability can be increased by "artificially" reducing the coupling between the explosion and its surroundings, i.e. by firing the explosion in an underground cavity. But before examining evasion by decoupling, two other evasion scenarios deserve review. In one of them, an evader would seek to disguise an explosion so that it produced seismic signals with earthquake-like characteristics; in the other, an evader would aim to mask the explosion signal by the signal produced by a concurrent large earthquake. The presence of the earthquake signal in effect increases the noise level above which the signal must be detected.

40. Any discussion of evasion in an arms control context gives rise to philosophical difficulties. Some argue that a State would not subscribe to a test ban agreement unless it was sure that it could continue to implement its defence policy without recourse to nuclear tests and therefore evasion technologies merit little consideration in assessing verification capabilities. Others argue that a State

might decide to adhere to a test ban because a ban would put an effective brake on nuclear developments by others whilst leaving it some freedom to continue with its own by the use of techniques which minimize the risk of non-compliance with a ban being discovered or substantiated. Between these extreme views, some recognize that a State might enter into a test ban régime in completely good faith but subsequently find that it had a pressing requirement for a few nuclear tests, e.g. as an essential part of a programme to justify a previously unsuspected serious fault in its nuclear stockpile of weapons. Such a State might then be tempted to employ evasion technologies, despite their difficulties, to satisfy this requirement as a preferable alternative to being seen to abrogate its Treaty obligations. There are also other possible positions that States might adopt between the two extremes. Careful judgement is required on where to place, within this wide spectrum of view, the proper weight to evasion scenarios. A reasonable possibility that clandestine testing at militarily significant levels could be conducted in these circumstances would not be an adequate basis for a CTB.

Multiple explosions

41. The most potent of the current identification techniques is provided by the $m_b : M_s$ criterion where an explosion is identified because its $m_b : M_s$ ratio is larger than that for an earthquake. If, however, a seismic monitoring station could be misled into believing a value of m_b from a smaller explosion and a value of M_s from a larger disturbance arose from a single event, the estimated $m_b : M_s$ ratio for that event would assume a value appropriate to an earthquake. This deception could be practised by firing a sequence of explosions with increasing yields. The standard practice would be to estimate the value of m_b from the first three or four seconds of the P wave on the seismogram and a value appropriate to the first small yield explosion would be estimated. The larger explosions later in the sequence if fired within a few seconds of each other would generate additive surface waves and cause a high value of M_s to be estimated. For a sequence of explosions, the short period P wave signals would obviously be complex, and hence earthquake-like, and the onset of the signal would be indistinct, because of the low yield of the first explosion, leading to uncertainty about the direction of first motion.

42. The effectiveness of this particular evasion scenario is debatable and is unlikely to be adopted without some experimental investigation into whether it could work. It might well not do so because, with broad band seismometers, it should be possible to measure the period of the P wave signal from explosions with yields of not less than a few tens of kilotons. For explosions this is normally in the one to two second range whereas for earthquakes, the dominant period is usually greater than two seconds. In any case, the seismograms from a temporally spaced and spatially separated sequence of explosions, while complex, may have features, including spectral differences, which a seismologist would not associate with an earthquake. If suspicions were aroused, detailed seismological study, on the basis of the developing understanding of earthquake sources, could show that the signal was not compatible with an earthquake origin. The basic weakness of the multiple explosion evasion scenario is that it makes no attempt to hide the seismic signals and hence the monitoring system would acquire data which, if properly interpreted, could identify that explosions had taken place.

Explosion masking

43. Evasion could be attempted by firing a nuclear explosion shortly after the start of a large earthquake with the aim of masking the explosion signal in the coda, i.e. the tail, of the earthquake signal after the conclusion of the main movement of the earthquake signal. Following a very large earthquake, the seismic noise level is raised significantly for several hours all around the world because of the overlapping of reverberations from the main shock and the numerous aftershocks. Consequently the detection thresholds will be worsened.

44. The effectiveness of this evasion scenario may be reduced by two factors. First, the explosion signal would come from a point spatially separate from the earthquake and by signal processing techniques this could be exploited to extract the explosion signal from the earthquake coda. Second, the earthquake could be at a distance from a particular seismic station where the amplitude-distance curve for P waves is close to a minimum whereas the explosion could be at a distance close to a maximum; again the explosion signal would then be more easily detected against the earthquake coda. Assessments suggest that, depending on the relative sizes of the earthquake and explosion, spatial discrimination could be helpful when the explosion and earthquake sources are at least 2° or 3° apart.

45. There would, of course, be considerable operational problems with practising this evasion technique. Its effectiveness would increase with the magnitude of the masking earthquake and with decreasing distance between the explosion site and the earthquake. Presumably, if this evasion measure were to be attempted, it would be essential to stipulate that the explosion should not be conducted until an earthquake with a magnitude in excess of a given magnitude and within a given range of the test site occurred. There would, however, be no way of forecasting the timing of this earthquake and hence the test would have to be held at almost instant readiness for perhaps a very long period, even if the test site were in a highly active seismic area. Evasion by a masking earthquake - or the hide-in-earthquake scenario - for testing well above the detection threshold of a monitoring network would clearly not be attractive but there are contexts where its disadvantages could be tolerable and hence it cannot be disregarded.

Decoupling

46. The third evasion technique is that of decoupling, i.e. the conduct of an explosion in a large underground cavity so that the explosion energy is transferred less well to its geological surroundings. Theory and experiment indicate that a decoupling factor of about 100 can be achieved at frequencies of about 1 Hz. Thus a fully decoupled 10 kiloton explosion would generate signals about 100 times smaller than for the same explosion close coupled in hard rock. Decoupling theory has been tested using chemical explosives (up to 1,000 kg) and a small nuclear explosion (yield 380 tons) but there is no experimental proof that decoupling would be as effective at higher yields, i.e. those of particular concern in a test ban context. However, there is no doubt that firing in a cavity would reduce the amplitude of the radiated signals to a greater or lesser extent.

47. The size of cavity required to achieve full decoupling increases with the yield of the explosion and there is debate about the maximum size of cavity which would remain sufficiently stable for a decoupled test. It is therefore not possible to estimate precisely how large an explosion could be effectively decoupled but the decoupling of several tens of kilotons cannot be ruled out. If fully decoupled by the cavity, such a test would give signals in the normal SP and LP recording bands no larger than those from several hundred tons yield close coupled in hard rock. The engineering problems of creating a cavity large enough to decouple several tens of kilotons is beyond the scope of this paper.

DEVELOPMENTS IN DETECTION AND IDENTIFICATION CAPABILITIES

Introduction

48. Having completed this diversion on evasion technologies, it is possible to return to the question of whether the detection and identification capability of seismic monitoring can be made adequate for test ban purposes. The attractions of working in the third zone (para. 13), i.e. at teleseismic distances, were so great that in

the 1960s and 1970s the forensic seismologists concentrated almost all their research on third zone detection and identification. A global teleseismic network would require relatively few stations - certainly fewer than the 180 originally described by the 1958 Conference of Experts; and they could be sited so as to have good noise characteristics. Perhaps, more importantly, the monitoring of any Party to a test ban treaty would not be critically dependent on the seismic data recorded by a station, or stations, on the territory of that Party even in those cases where the territory was very large. The discussion so far in this paper, however, suggests that the performance at teleseismic ranges has its limitations. Taking the decoupling evasion scenario into account, it has been seen that there is a possibility that a test of some tens of kilotons could be carried out without producing seismic signals above the detection threshold. For those seismic signals above the teleseismic detection threshold, there are still shortcomings in achievable identification performances. The monitoring system would be left annually with a considerable number of events which could not be unambiguously identified as earthquakes and this could sap confidence in Treaty compliance. Suspicions might grow that the unidentified events concealed one or more nuclear explosions.

49. In view of this situation, over the past eight or so years, attention has turned back to the performance of stations in the first and second zones, i.e. at so-called regional ranges. This change of emphasis was encouraged by the difficulty of measuring M_b for low magnitude disturbances, especially explosions, so that the $m_b : M_s$ criterion could not be applied.

Regional data for the $m_b : M_s$ criterion

50. The surface waves, whose amplitudes are measured by M_b , decay continuously with distance from the source and hence the nearer the receiver is to the source the better. A further advantage of obtaining a higher signal-to-noise ratio by having a smaller source/receiver distance is that the number of overlapping surface waves from other disturbances is reduced. Long period seismograms at regional distances are therefore potentially advantageous for identification purposes and could reduce, if not eliminate, the present 0.5 magnitude unit gap which currently is estimated to exist between the teleseismic detection and identification thresholds.

Detection and identification at regional distances

51. Because of the shape of the curve of P wave amplitude decay with distance - rapid decay out to about 5° and slow decay from 30° to 90° (see para. 13) - the amplitude of the P wave observed 5° from a disturbance may be little larger than at long range. So usually only by having stations within 5° of any epicentre will the signal-to-noise ratio for P be greater than seen at teleseismic distances. For many regional SP seismograms however the largest amplitude arrival is not the first arriving P wave but the so-called Lg phase which is a high frequency surface wave that arrives many seconds after P. The Lg wave decays much more slowly with distance than P. There is thus a lower detection threshold for Lg waves than for P. Unfortunately, it is necessary to record P to be able to use the established procedures for determining the epicentre of a disturbance and for measuring m_b , which is required to allow the $m_b : M_s$ identification criterion to be applied. Much effort has been put into the search for methods of identifying sources using the Lg phase alone or in conjunction with other regional phases but so far these have been unsuccessful. It has thus not been possible to take advantage of the lower detection threshold of Lg waves compared to P waves to lower the identification threshold. However, the detection of S waves at regional distance improves the accuracy of source depth estimation.

Monitoring at high seismic frequencies

52. Until about a decade ago, it was assumed that the imperfections in the elasticity of the earth would introduce an attenuation of a factor of more than 20 in P waves as a frequency of 1 Hz propagated over long distances. If this were true, then it was argued this so-called anelastic attenuation at high frequencies, say at about 5 Hz, would be enormous, i.e. a factor approaching 10^4 . The original assumption is now known to be badly in error. In fact, anelastic attenuation at 5 Hz is probably only about a factor of 20 over some transmission paths. Consequently signal amplitudes at 5 Hz at long range must for some paths be very, very much larger than originally envisaged.

53. The ambient noise spectrum (see paragraph 11) at quiet sites falls steeply with increasing frequency above a frequency of about 0.2 Hz - perhaps at a rate of about 40 db per decade - and hence, despite the relative anelastic attenuation differential between 1 Hz and 5 Hz signals, it might be more profitable in some circumstances to search for long range signals at 5 Hz than at 1 Hz. Some support for this view comes from the teleseismic detection of 8 Hz signals from explosions at the E. Kazakhstan Test Site. It is, however, too early to say whether high frequencies offer a means of improving over-all monitoring effectiveness.

54. There is another reason for investigating the possibilities of monitoring at higher frequencies. There is evidence that as the yield of an explosion is decreased, the proportion of the P wave energy at higher frequencies increases. There is also evidence that the proportion of high frequency energy in the P wave signal from a decoupled explosion is greater than in the signal from a close coupled explosion of the same yield; in other words, the efficiency of decoupling appears to be frequency dependent and theoretical predictions indicate that if a decoupling factor of 100 applies at 1 Hz, the factor at 5 to 10 Hz could be as little as 5.

55. It appears from the above that there are possibilities for test ban monitoring in observing higher seismic frequencies than have hitherto been considered. At the moment there are far too few data points to allow assessments to be made and conclusions to be drawn. It will be necessary to demonstrate that high frequency signals can indeed be detected over a variety of source/receiver paths and to investigate whether the sources of detected high frequency signals can be identified as earthquakes or explosions with adequate assurance. If a high frequency programme were successful in these respects, there would be promise of at least a partial technical solution to the low yield and the decoupled explosion problems. However, for monitoring against low yield decoupled explosions, regional stations would certainly be required because the seismic magnitudes would be equivalent to a strongly coupled explosion of 200 tons or less.

A GLOBAL MONITORING NETWORK

56. A negotiated ban on underground nuclear testing would certainly demand the setting up of a global seismic network for monitoring at teleseismic ranges. How such a network would be provided has not been decided although the activities of the ad hoc Group of Scientific Experts (AHGSE) appointed by the Conference on Disarmament suggest that Parties to a Treaty would contribute existing stations to the network. If this were the case, the network would not be optimized from the technical point of view; the locations of stations would not be ideal for the global monitoring role and the equipment at some stations would not be of the highest possible quality. The stations already co-operating with the AHGSE are estimated to provide a detection threshold which varies from about $m_b 4$ in some

parts of the world to $m_b 5$ or greater in other parts, notably in the Southern Hemisphere. The AHGSE assesses that an optimized network would have a detection threshold of not higher than $m_b 4.4$ throughout the world. This is higher than the $m_b 4$ quoted in paragraph 18 in part because no account was taken of the possibility of ocean-bottom seismometers contributing to the monitoring of those areas where land-based monitoring is less effective.

CONCLUSIONS

57. On the basis of data currently available, it is estimated that a properly designed and deployed global network of seismic stations would achieve a detection threshold of $m_b 4$ and an identification threshold of $m_b 4.5$ throughout the world. With such a network it might be thought that any nuclear test with yield above a few tens of kilotons would be discovered. However, militarily significant testing can be conducted at yields beneath this level. Furthermore, this assessment of the detection and identification threshold must be treated with caution. It rests on data which are highly selective and it represents a considerable extrapolation from results obtained on essentially a research basis. Confidence would be enhanced if valid data were widely available from nuclear explosions in areas away from the very few existing nuclear testing sites, e.g. from areas which are potentially difficult to monitor, and from explosions carried out under conditions which might make verification less effective. Beyond the need to acquire more basic data on the effect of test conditions and monitoring efficiency, there is a requirement for experimental experience on the implementation and operation of a monitoring teleseismic network to demonstrate that the performance estimated from research programmes can be achieved in practice. Given the severe security implications of a test ban, it would be unrealistic to expect States to subscribe to a Comprehensive Treaty unless there can be a high assurance that estimated verification performances would be achieved, and that they would effectively preclude the possibility of clandestine testing at military significant levels.

58. At least for the present, it appears that monitoring at teleseismic ranges by itself, would be insufficiently effective to permit a test ban to be brought into force. Paragraphs 48 to 55 describe how the shortcomings of teleseismic monitoring might be made good, at least to some extent, by the addition of monitoring at regional ranges. It is, as yet, too early to estimate how effective regional monitoring might prove to be; the outcome of current research programmes has to be awaited and it should then become clear whether a politically, technically and economically acceptable basis for regional seismic verification networks can be devised.

CONFERENCE ON DISARMAMENT

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10 July 1985
ENGLISH
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LETTER DATED 9 JULY 1985 ADDRESSED TO THE PRESIDENT OF THE CONFERENCE ON DISARMAMENT FROM THE REPRESENTATIVE OF THE USSR TRANSMITTING THE TEXT OF THE REPLY OF THE GENERAL SECRETARY OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE SOVIET UNION, Mr. MIKHAIL GORBACHEV, TO THE UNION OF CONCERNED SCIENTISTS, PUBLISHED ON 6 JULY 1985

I have the honour to transmit herewith the text of the reply by Mr. M.S. Gorbachev, General Secretary of the Central Committee of the CPSU, to a letter from the United States public organization "Union of Concerned Scientists", published on 6 July 1985.

I should be grateful if you could arrange to circulate this text as an official document of the Conference on Disarmament.

(Signed) V. ISSRAELYAN

OUTER SPACE MUST SERVE PEACE

Reply by Mr. M.S. Gorbachev to a letter from the
Union of Concerned Scientists

Dear Mr. Kendall,

In reply to the letter sent by you on behalf of the Union of Concerned Scientists containing an appeal for the prohibition of space weapons, I wish to say that I feel profound respect for the opinions of eminent scientists who recognize more clearly than many others, the dangerous consequences for mankind which the spread of the arms race to outer space and the transformation of outer space into an arena of military rivalry would entail.

The Union of Concerned Scientists rightly demands that a clear and irreversible political decision should be taken to prevent the militarization of outer space and leave it free for peaceful co-operation. The problem truly calls for a bold approach. Yesterday's yardsticks, narrow ideas about one-sided benefits and advantages - illusory in any case - will not do here. Now, as never before, what is needed is a far-sighted policy based on an understanding of realities and of the dangers we shall inevitably encounter tomorrow if those who can and must take the only right decision shirk their responsibility today.

On behalf of the Soviet leadership I should like to state in all certainty that the Soviet Union will not be the first to take weapons into outer space. We shall make every effort to persuade other countries too, and above all the United States of America, not to take such a fatal step, which would inevitably increase the threat of nuclear war and spur on an uncontrolled arms race in all directions.

With this goal in view, the Soviet Union, as you must surely know, has submitted a radical proposal in the United Nations - a draft treaty on the prohibition of the use of force in outer space and from space against the Earth. If the United States of America joined the overwhelming majority of States which have supported this initiative, the question of weapons in space could be closed once and for all.

At the Soviet Union-United States negotiations on nuclear and space arms in Geneva we are endeavouring to reach agreement on a complete ban on the development, testing and deployment of strike systems in outer space. Such a ban would not only make it possible to preserve outer space for peaceful development, exploration and scientific discovery but also to embark upon a process of radical reduction and destruction of nuclear weapons.

More than once, we have also taken unilateral action intended to give the United States a good example. The moratorium placed by the Soviet Union on the stationing of anti-satellite weapons in outer space has now been in force for two years, and will remain in force for as long as other States act in the same way. Our proposal that both parties should completely cease work on the development of new anti-satellite systems and that the systems which the USSR and the United States of America already possess, including those whose testing has not been completed, should be destroyed lies on the table in Washington. The actions of the United States side will very shortly show what solution the United States Administration is going to prefer.

Strategic stability and confidence would undoubtedly be strengthened if the United States of America together with the USSR agreed to reaffirm in binding form its commitment to the régime of the Treaty on the Limitation of Anti-Ballistic Missile Systems, which is of unlimited duration. The Soviet Union is not developing any space strike weapons, a large-scale anti-ballistic missile system or the basis for such a system; it is abiding strictly by its obligations under the Treaty both as a whole and in its several parts; and it is unswervingly observing the spirit and the letter of that most important document. We invite the United States leadership to join us in this matter and to renounce the plans being nurtured for the militarization of outer space, plans which will inevitably lead to the scrapping of that document, the key link in the entire process of nuclear arms limitation.

The USSR is proceeding from the belief that a practical solution of the problem of preventing an arms race in outer space and terminating it on Earth is possible provided both sides have the political will and a sincere desire to strive for that historic goal. The Soviet Union has that desire and that will.

I wish the Union of Concerned Scientists and all its members success in their noble activities in the cause of peace and progress.

Yours sincerely,

M. GORBACHEV

Pravda, 6 July 1985

FEDERAL REPUBLIC OF GERMANY

Working Paper

A Proposal for the Establishment and Progressive
Improvement of an International Seismic Monitoring
and Verification System relating to a
Comprehensive Nuclear Test Ban

A. Introduction

Agreement on the conclusion of a Comprehensive Nuclear Test Ban Treaty embracing all nuclear weapon tests as well as nuclear explosions for peaceful purposes continues to be seen in the international arena as one of the most important elements in the quest for disarmament and arms control. In the Partial Test Ban Treaty of 1963 Contracting Parties expressed their determination to achieve the discontinuance of all test explosions of nuclear weapons for all time and to continue negotiations to this end. In its Preamble, the Non-Proliferation Treaty (NPT) of 1968 recalls this resolve by all States Parties and establishes in its Article VI the obligation to conduct negotiations on nuclear disarmament in good faith. Reference is also made to the relevant paragraphs of the Final Document of the First Special Session of the General Assembly devoted to Disarmament..

In striving for an agreement on a Comprehensive Nuclear Test Ban Treaty, extensive work has been accomplished by many delegations, and a substantial number of Working Papers have been presented from the early days of the Conference of the Eighteen-Nation Committee on Disarmament. In view of the significance in terms of military security and the destabilizing effects which might result from the advantages that one state might draw from undetected unilateral testing, these efforts have mainly addressed problems relating to

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the verification of a CTBT, in particular verification based on seismic technology, and to a lesser extent aspects of institutional arrangements for verification systems or comprehensive drafts for a CTBT.

The specific purpose of the present Working Paper is to build upon these earlier accomplishments - taking into account especially contributions from Australia, Japan, Norway and the Group of Scientific Experts - and to integrate them into the novel concept of a seismic monitoring and verification system evolving dynamically over time.

Chapter B describes the nature of this project and the rationale behind this approach.

Chapter C outlines the scientific/technical measures required to upgrade over time the detection and identification capabilities as well as the operating mode of the proposed seismic monitoring and verification network.

Chapter D describes the institutional arrangements for a future seismic verification system under a treaty regime.

Chapter E presents an institutional framework for the transitional period during which a seismic monitoring and verification system would gradually evolve in the absence and pending the elaboration of such legal instrument.

B. The Progressive Establishment of a Global Seismic Monitoring and Verification System

Most intellectual contributions to a seismic verification system so far have visualized the functioning of such a system only in the framework of a full-fledged Comprehensive Nuclear Test Ban Treaty. By contrast, the purpose of this Working Paper is to propose the establishment and continuous

operation of an international monitoring and verification system based on seismic technology at the present stage, without awaiting the conclusion of a CTBT or other related contractual arrangements, which would continue to unfold under a treaty regime.

In a first phase, the international seismic data exchange system, as tested in 1984, should be put into operation on a permanent basis. In subsequent phases this system should be gradually improved in a learning-by-doing process, and brought up to a standard which would match the specifications of the most advanced network as described in the first report of the group of scientific experts (CCD/558), eventually even surpassing it with the aid of new technological developments. While efforts to agree on a Comprehensive Test Ban Treaty continue, an increasingly sophisticated seismic verification system would mature to meet the verification requirements of all parties concerned, so as to be fully operational at the time of the conclusion of a CTBT. In a dynamic interaction of theoretical development and practical experience, the scientific community could strive to resolve the remaining problems of a seismic verification system in all its aspects: system operation, network detection and identification capability, magnitude-yield estimation, evasion possibilities.

A summary which describes the development of such a verification system is given in the next paragraph. A detailed description will be included in a supplementary technical report.

The financial implications of the establishment of such a comprehensive system, especially in its later, technically more advanced stages deserve separate consideration and will have to be addressed at the appropriate time.

C. A System Design for the Gradual Improvement of Monitoring and Verification Capabilities for a Comprehensive Nuclear Test Ban

The objective is the incremental upgrading of the experimental data exchange system as used during the Group of Scientific Experts Technical Test in 1984 with a view to establishing a functioning, permanently available monitoring and verification system.

The capability of the system to detect and identify explosions would be gradually increased as the system is conceptually and technically improved. Improved system operation characteristics would come about in a sequence of phases. Each phase would be characterized by a different degree of sophistication as far as technical equipment and standardization of operation is concerned and would allow for verification at different levels of magnitude or respective yield levels. Due to inadequate calibration data on source environments and source-receiver paths, magnitude levels can be correlated to yield values only within a relatively broad range.

The approach used in this section distinguishes between verification on a global and a regional level.

The international data exchange system would operate on a global scale and its establishment and operation would be the responsibility of both non-nuclear-weapon and nuclear-weapon states.

In-country networks, consisting of several interrelated stations or arrays, on the other hand, would have to be the subject of separate arrangements among nuclear-weapon states which would include specifications on test sites and calibration parameters to allow for as high a degree of confidence as possible in verification efforts. The calibration data exchanged or collected among the nuclear-weapon states would be made available to non-nuclear-weapon states, thus adding a desirable degree of redundancy to the verification system.

1. Use of Verification Capabilities of Existing Seismic Installations

In a base model a monitoring network of 50 to 100 stations, as specified by the GSE, would comprise existing seismic stations, existing lines of communication, and existing facilities for the collection, analysis, and dissemination of seismic data. This network, called GSE network below, would by and large correspond to the global seismic data exchange system as operated during the 1984 test run.

It is estimated that the level of verification of this system would equal a magnitude of roughly 5.0 (mb). This corresponds to a yield of approximately 100 kilotons (Kt), in the event that seismic signals of explosions are muffled by virtue of dry unconsolidated rock. In wet hard rock the corresponding yield can be as low as 10 kt.

A network that would meet these specification could be operational after a period of about two years.

Station operation and maintenance would be provided by the countries hosting the seismic facilities.

System upgrading:

- * The international data exchange system would be operated in an extended test mode based on experience from the 1984 GSE technical test. International Data Centers (IDCs) would be set up and operated in specified countries. The data reported by this system would be limited to the basic parameters of detected seismic signals (Level I data). A network of stations based on an appropriate geographical distribution of existing facilities would be defined and incorporated into the monitoring system as much as possible. Fully analyzed data would be distributed within one week.

- * The GSE would develop detailed specifications for stations that are to participate in the future monitoring network. These specifications would include agreed technical characteristics of the sensors, electronics, and recording equipment, as well as the minimum acceptable site characteristics. Where desirable, all of the data from these dedicated stations would incorporate a data authentication scheme.
- * Prototypes of the dedicated stations would be tested and installed at a number of locations.
- * Test runs would be conducted by the GSE for the rapid exchange of seismic waveform data (Level II data) in order to promote the practical availability of this technology.

2. Improvement of Teleseismic Verification Capabilities

Once in operation, the basic international seismic monitoring system would be gradually refined and its capability to detect and identify explosions improved.

By using the inherent capabilities to full extent the verification capability of the GSE network could be upgraded to a level of magnitude 4.7 (mb), which corresponds to a yield of 50 kt and would encompass the possibility of detecting and identifying muffled seismic signals that result from detonations of this yield in dry unconsolidated rock. In comparison the equivalent yield for a magnitude 4.7 (mb) explosion in wet hard rock could be as low as 5 kt.

In essence, the verification system would consist of the GSE network, however, it would contain additional stations and would be operated on an improved technical level.

Further system upgrading includes:

- * All dedicated stations, operating by standardized specifications, would be installed at those locations which meet the system design criteria for optimal global coverage.
- * Operation of International Data Centers would include exchange of Level II data on a routine basis. Data would be made available and distributed by IDCs.
- * Modern telecommunication systems and real-time communication by satellite would be set up for transmission of data within the international seismic data exchange system.

These improvements should bring the verification capability of the global seismological monitoring system to a level of magnitude 4.0 (mb) which corresponds to a yield of 5 to 10 kt taking into account the possibility of muffled signals from explosions in dry unconsolidated rock or to a yield of about 1 kt for explosions in wet hard rock.

For obvious reasons, time-frames are difficult to set with precision. However, these improvements in verification capability could well be achieved after periods of approximately 4 and 8 years, respectively, from the time the continuous operation of the international data exchange system is initiated.

3. Implementation of In-Country Networks

In addressing the verification capability of a seismic monitoring system particular importance must be attached to the possibility of evading detection by decoupling explosions in a cavity.

The implementation of internal networks, in particular in the territory of nuclear-weapon states, would effectively improve the verification capability by lowering the verification level - within the region - to magnitude 3.0 (mb). This would offer realistic possibilities for detecting and identifying evasion attempts involving yields of 10 kt or greater.

The detection and identification of evasion attempts down to the level of 1 kt would obviously require a much larger technical input. In-country networks with borehole stations or arrays spaced over distances of 500 to 1000 km - in areas where cavity decoupling is possible - would appear to meet these requirements.

System upgrading:

- * In the in-country networks the installation of additional arrays or borehole stations would be continued until the envisaged level of verification is achieved.
- * Data on important geological and geophysical parameters as well as other data required for calibration purposes would be exchanged.
- * Real-time communication by satellite and modern telecommunication systems would allow IDCs full access to the data from arrays and dedicated stations.

D. Institutional Arrangements under the Auspices of a
Fully Negotiated Test Ban Treaty

The final elaboration of institutional arrangements for the verification and compliance chapters of a CTBT will be incumbent upon the negotiators to such a treaty. A first comprehensive description of an institutional framework that might form part of a CTB-Treaty is, however, included in the interest of providing a logical sequence for the evolution of institutional solutions from a pre-treaty stage to the definitive stage of contractual arrangements.

It is suggested that the institutional structure of a verification system based on seismic means comprise three organs:

- a Consultative Committee as the body endowed with political decision-making powers;
- a Committee of Experts as the organ with operational functions representing scientific/technological expertise and charged with the task of co-ordinating the implementation and continuous operation of an international data exchange system;
- a Secretariat as the body with administrative-supportive functions.

This three-organ structure is also reflected in other working papers, though the task as well as the decision-making and/or operational powers differ.

1. Consultative Committee

The Consultative Committee should be the principal organ with decision-making powers in which all States

Parties to a treaty or a seismic verification agreement are represented and which supervises the work of the Committee of Experts and the Secretariat. With regard to the operation of a seismic monitoring and verification system, the following duties should be assigned to the Consultative Committee:

- to supervise and review the implementation and continuous operation of such a system based on the reports provided by the Committee of Experts;

- to decide on, and recommend to States Parties, quantitative and qualitative improvements of the international seismic data exchange system as proposed by the Committee of Experts;

- to be a forum for consultation and co-operation in which any Party can make inquiries and receive information as a result of those inquiries;

- to be a forum in which any Party can lodge a complaint and request an on-site inspection and to which a factual report of the inspection is presented;

- to decide on budgetary questions.

The Consultative Committee should decide on the basis of consensus with the exception of questions that concern procedural problems and personnel decisions, where a majority of those present and voting would be sufficient. The Consultative Committee should meet once a year and should assemble for extraordinary meetings upon the request of a State Party.

In order to be represented during its periods of recess the Consultative Committee should establish an "Executive Group" comprised of a chairman elected for a period of two years and fifteen (15) members, of which five should be permanently appointed representing the nuclear-weapon states. The remaining ten members should be selected by the Consultative Committee on the basis of an appropriate geographical balance and should serve for two years, with five members being replaced every year. The "Executive Group" would take on special functions with regard to complaint procedure and would be the addressee for communications from States Parties to the Consultative Committee.

2. Committee of Experts

Of the three organs, the Committee of Experts should be the operative element in the institutional set-up for a seismic verification system. It should be the primary task of the Committee of Experts to ensure the implementation and smooth functioning of an international seismic data exchange system. The Committee of Experts should be in charge of all scientific/technical aspects of a seismic monitoring and verification system and should be given executive functions in these matters while being responsible to, and dependent on the decisions of, the Consultative Committee.

The Committee of Experts could be composed of 15 scientific experts who would be appointed by the Consultative Committee from among candidates nominated by States Parties. With respect to the composition of the Group, due regard should be paid to adequate geographical distribution. Experts should serve for a period of five years in the Group with three experts being replaced every year.

The Committee of Experts should be entrusted with the following duties:

- to oversee and co-ordinate the implementation and continuous operation of the international data exchange system;

- to develop standards for the technical and operational characteristics of participating seismic stations, international data centers, and data processing as well as data transmission;

- to review the operation of the seismic monitoring and verification system and to consider and recommend improvements;

- to identify on-site inspection techniques and to conduct international on-site inspections, according to agreed procedures, at the request of the Consultative Committee and to report the result of such inspections to the Committee;

- to be a forum for technical discussions with respect to events for which a Party seeks clarification;

- to maintain contact with the international data centers, with the appropriate national authorities of States Parties, and the WMO;

- to undertake technical studies upon the request of the Consultative Committee.

In executing its functions the Committee of Experts should draw on the expertise and work accomplished by the Group of Scientific Experts (GSE). The Secretariat should assist the Committee of Experts in organizational and administrative questions.

The Committee of Experts would meet twice a year and upon the request of the Consultative Committee. It would elect its own chairman and establish its own rules of procedure. Matters of substance would be decided by consensus. Where a consensus is not possible the differing views would be presented without bias in one comprehensive report. Other matters would be decided by a majority of the Committee. An annual progress report would be submitted to the Consultative Committee. All reports and studies prepared by the Committee of Experts would be distributed to all States Parties.

3. Secretariat

The Secretariat, comprised of a Director and a small staff, should assist the Consultative Committee and the Committee of Experts in all matters of an organizational, administrative, and financial nature.

4. Complaint Procedure

If a State Party seeks clarification or requests an international on-site inspection with regard to an event on the territory of another State Party it has a choice of bilaterally addressing the State concerned and/or directing its request to the Consultative Committee through its Executive Group. In any case States Parties should feel obliged to provide appropriate information and to co-operate in the most effective way possible in order to dispel suspicions of non-compliance.

In the case of an on-site inspection the Consultative Committee, represented by the Executive Group, should, in consultation with the State Party in whose territory the inspection is to be conducted, determine:

- the composition of the inspection team (members of the Committee of Experts and, if necessary and appropriate, additional experts drawn from a list pre-compiled in co-operation with the Consultative Committee);

- the time and duration of the inspection;

- the area of inspection;

- the inspection techniques.

The inspection team would present a report to the Consultative Committee which would reflect in a factual manner the results of the inspection and not attempt to assess any data collected. In principle, the report should be based on consensus; where this is not possible, the report should reflect the different views prevailing in the inspection team.

E. Institutional Arrangements for a Transitional Period

1. During the period when a Comprehensive Test Ban Treaty has not been ratified, in other words, when no appropriate international legal instrument exists of which the provisions for a seismic monitoring and verification system could become a part, a transitional institutional framework would be needed to set in motion the seismic monitoring system described in this paper. As suggested above, a seismic monitoring and verification system should be started on the basis of the international seismic data exchange system as operated during the technical test run of 1984, with the intention of improving the system in qualitative and quantitative terms while in permanent operation. During that transitional period, i.e. until the conclusion of an international legal instrument concerning underground

nuclear testing, the following functions, which would eventually be assumed by the Committee of Experts, could be assigned to the Group of Scientific Experts:

- co-ordinating the implementation and continuous operation of an international seismic data exchange system;
- drawing up recommendations for the improvement of the present network with regard to the seismic equipment at national seismic stations, means of data communication, equipment of international data centers, and standardized procedures for data processing and redistribution;
- maintaining contact with and co-ordinating the work of the international data centers, the competent national authorities, and WMO;
- serving as a forum for scientific/technical discussions;
- carrying out technical studies.

Under past and present mandates the GSE has already engaged in executing some of these functions, namely the theoretical development of an international seismic data exchange system and, at least in part, the testing of the envisaged network. Essentially new would be the operational task of co-ordinating the permanent establishment and of reviewing the continuous operation of a global seismic monitoring system. Its new responsibilities should be assigned to the GSE in a mandate which the Conference on Disarmament should consider some time after the conclusion of the detailed report on the technical test run of 1984.

2. The responsibilities of the Consultative Committee, the organ which should hold the political decision making powers, would be carried out during the transitional period by the Conference on Disarmament. The GSE would, as in the past, report to the Conference on Disarmament which, in turn, would adopt the reports based on consensus decisions, approve recommendations of the GSE, and entrust the GSE with further tasks.

3. The Secretariat of the Disarmament Department of the United Nations would provide assistance and support in organizational and administrative matters as it does for the Conference on Disarmament.

Under this institutional arrangement, the Conference on Disarmament, the GSE, and the Secretariat of the Disarmament Department, would represent the predecessor bodies for the envisaged Consultative Committee, the Committee of Experts, and the Secretariat respectively. Within the framework and under the guidance of this transitional set-up the present international seismic data exchange system, as tested in 1984, would be operated on a permanent basis and, while in operation, progressively improved.

Upon the conclusion of a CTBT, the technical means for an international seismic monitoring and verification system would be available and operating and the transitional institutional arrangement would be succeeded by the permanent one.

YUGOSLAVIA

PERMITTED ACTIVITIES

VERIFICATION MEASURES */

Upon entry into force of the Chemical Weapons Convention, two types of permitted activities would need to be considered:

- (a) permitted activities for protective purposes, and
 - (b) other permitted activities.
- (a) Permitted activities for protective purposes

The permitted activities for protective purposes imply all activities aimed at the research, development and production of protective items and medicaments-antidotes. Some of these activities may create doubt about the compliance with the Convention and thus lessen confidence among States Parties. In order to avoid this and to enhance mutual confidence, it would be necessary, to define the following parameters: the type of toxic chemical, the criteria and measures of verification.

As far as the type of toxic chemicals is concerned, there are very different chemical structures which include a wide range of compounds. This creates a complex picture of the problem and difficulties for the monitoring of the research and development, as well as the implementation of verification measures.

A somewhat clearer view would be provided if all toxic chemicals were classified into groups according to their effects on the living organisms, and if a model substance was chosen on the basis of its application to living organism. Such an approach permits consideration of only a few groups of toxic chemical compounds:

- nerve gases;
- neuro-toxic compounds;
- skin poisons;
- blood poisons;
- cell poisons;
- irritants and psycho agents, etc.

If the criteria of toxicity were also to be taken into account, the number of toxic compounds could be reduced to a reasonable extent. Thus, for example,

*/ See CD/393, CD/401 and CD/482.

all poisons from the group of nerve poisons that are used for protective purposes, belong to the group of "super-toxic lethal chemicals" and the same criterion could be applied to all of them. Consequently, they can be subject to the same verification measures. The pesticides and derivatives of phosphorous organic compounds and carbamic acid would naturally be excluded.

The quantities of toxic chemicals used for permitted-protective purposes are determined on an agreed basis up to one metric ton.

1. Small-scale production facilities are for the purpose of CW Convention, considered as facilities designed for the production of super-toxic chemicals for protective purposes in particular. The prevailing view is that this type of facility should produce toxic chemicals in aggregate quantity (up to one metric tonne per year). Such facility should not therefore be larger than the ordinary pilot plant.

In negotiations so far opinions were expressed that such facilities should be allowed to produce the aggregate annual quantity of all super-toxic chemicals-chemical warfare agents permitted under the Convention. This mostly refers to the production of super-toxic lethal chemicals. The concentration of production in one place would be most appropriate from the point of international verification.

As described in the Finnish paper (CD/CW/WP.92), this type of facility should be flexible and independent enough to allow production of different toxic chemicals, monitoring of the production process and the filling of samples for protective purposes. This facility in the production process should, in the view of the Yugoslav delegation, comprise the following elements: storages for raw materials; production (intermediates, final products); control analysis (analytical laboratory), storages for products and intermediates; filling facilities and destruction of wastes.

The facility would in general produce super-toxic lethal chemicals and their key precursors. Consequently, the production should be divided into:

- (a) the facility for the production of key precursors, and
- (b) the facility for the production of final products.

Similarly, two types of reaction vessels (reactors) may be used for carrying out the reaction of fluorination in the first vessel, and the reactions of acylation, alkylation, esterification, etc. in the second vessel. The first reactor should be specially designed to permit to carry out in it the reactions with hydrogen fluoride acid and its derivatives, while the second one could be enamel-glazed.

The capacity of the facility should be separate for each product: for key precursor and for super-toxic chemical. The number of reactor vessels will thus depend on the number of chemical warfare agents to be produced in the facility.

The production of these agents and the processes carried out in the facility should be automated, and automatic recorders should be placed at crucial points to record material and energy balances: inflow of chemical, pressure and temperature, etc. The data collected should be stored in a computer. All analytical data, spectra, diagrams, etc. should be stored in the control

laboratory analysing the quality and quantity of raw materials, intermediates and products. It is very important that all data relevant to the production be collected and stored in a computer centre. The storages for raw materials, intermediates and products should not exceed the storage capacity permitted under the Convention (aggregate capacity of the final product of one metric tonne).

The filling facility (room) is used for filling the samples and devices to be used for research of the protective effects. This facility should be provided with adequate equipment for filling and control of the material balance.

Bearing in mind the fact that this type of facility is used for the synthesis of highly toxic chemicals, of chemical warfare agents for the most part, it should be effectively automated. Automation would be needed for effective data recording, monitoring of the production and process control. The monitoring of all wastes would also be necessary. The monitoring of the production should, on its part, meet the basic requirements of continuous control of the material and energy balances of the synthesis and storage of the data in a computer centre.

(b) Other permitted activities

1. Laboratory synthesis

The laboratory synthesis implies research of new chemical structures mainly for the (purpose of the) pharmaceutical industry and the production of pesticides (protection of plants). The quantities thus synthesized range from 1 to 100 grammes. The toxicity of the synthetic compounds can be wide-ranging, namely from super-toxic to other harmful chemicals. Having in mind the nature of the laboratory synthesis (its research character; synthesis of small quantities; variety of chemical structures) the control of the syntheses and the quantities produced is very complex and difficult to perform at the international level. On the other hand, although the quantities which are laboratorically synthesized are not of military significance, there is nevertheless potential risk that at a given moment and with necessary development, they may be produced for military use. In addition, the laboratory synthesis improves knowledge about the effects of any new synthesized chemical warfare agents on the living organisms and their efficiency; of the new chemical structures, and of the military usefulness of these chemicals. This stage is therefore the most complex one in the development of new chemical weapons and in reality, an effective control of it is very unlikely.

2. Small-scale production facilities

Having in mind the proposals put forward by many delegations that the Convention should not prevent the development of the chemical, and pharmaceutical industry in particular, the Yugoslav delegation considers that there is a need to examine the possibility of producing super-toxic lethal chemicals for other permitted purposes. Namely, the rapid development of synthetic organic chemistry over the past decades has brought about new methods of synthesis of biologically active chemical compounds whose structure is similar to that of natural compounds. Some of these compounds are highly toxic, but have nevertheless, certain therapeutic characteristics which are increasingly being used in the treatment of many diseases. Due to their high toxicity, the doses of these chemicals used in human treatment are very small. Consequently, the production of these compounds

can be carried out in a pilot plant. In the view of the Yugoslav delegation, the annual production of these super-toxic lethal chemicals for other permitted purposes should not exceed one metric tonne, and only exceptionally their production should be maximally two metric tonnes per year. The number of such facilities will depend on the development of the pharmaceutical industry. The facility, however, should be so designed to permit full automation and monitoring at all stages of the production process. As in the case of small-scale production facilities for protective purposes, these facilities also should be equipped with instruments for recording aggregate material and energy balances and all parameters (pressure, temperature, etc.) in the process of synthesis. The size of the reaction vessel (reactor) in the final technological stage should not be greater than 250 litres. The facility should include all the elements of a small-scale production facility, except for the filling room.

3. Large-scale production facilities or industrial facilities

Facilities of this type are used for the production of dual purpose chemicals and precursors. The chemicals manufactured in such facilities belong to the so-called products for other permitted purposes and are basically intermediates in the industrial technological process. Such compounds today are widely used in the civil chemical industry for the production of many organic products (in pharmaceutical industry, plastics, production of pesticides, etc.).

Depending on the technological process and the capacity of the large-scale facility, methods will have to be devised to monitor the production for verification purposes.

As the designated chemicals are by and large precursors or intermediates used in the process of synthesis of a civil chemical industry, technology and the facilities in which they are produced are part of a chemical plant.

At best, under the terms of the Convention, the capacity of the facility for the production of dual-purpose chemicals and precursors should be such as to meet the requirements of the complete technological process at the plant. In other words, the annual output of the designated chemical at the plant working with full capacity (24-hour production) should be completely processed into the final product. Therefore, the storages for intermediates (dual-purpose chemicals or precursors) should not exceed 30 per cent of the daily output.

Further, the monitoring system and control of the production of dual-purpose chemicals (phosgene, cyanogen, chloride, hydrogen cyanide, etc.) should be such as to permit automatic recording of the material and energy balances.

Moreover, it would be necessary to ensure adequate recording of the parameters such as temperature and pressure inflow of the raw materials and outflow of the product.

The material balance of dual-purpose chemicals and precursors can also be proved by the control of the final product in the over-all technological process.

Thus, for example, the production of phosgene should be automatically controlled and monitored by a computer (Annex I). The whole process can be controlled in this way, and the data collected can be used for reports and control of the transfer and diversion of intermediates into the final product.

Verification measures of the declared facilities

Within the framework of the permitted purposes, each State Party may have facilities for the production of chemical warfare agents which could be used for research of the protective effects, toxic chemicals for medical and agricultural purposes, as well as facilities for the production of chemicals used as intermediates in the civil chemical industry (other permitted activities). Such facilities should be declared by providing the following information:

- (i) the location and name of the company or organization operating the facility;
- (ii) chemical name and formula of all dangerous chemicals (CWA, precursors, dual-purpose chemicals, etc.);
- (iii) detailed technology equipment for automated process;
- (iv) end use of intermediates;
- (v) whether the whole quantity of the chemical is used in situ or at another plant or is it exported?
- (vi) full name of the plant using the chemical for further processing;
- (vii) the State(s) to which the chemical is exported;
- (viii) maximum annual design capacity of the plant in tonnes;
- (ix) the quantities to be exported;
- (x) aggregate annual output of all chemicals;
- (xi) aggregate annual use of the designated chemical for processing into other chemical products;
- (xii) manner of reporting to the international organization;
- (xiii) proposed verification.

Verification of small-scale production facilities

Bearing in mind that such facilities mainly produce CW agents belonging to the group of super-toxic lethal chemicals and their key precursors, and pharmaceutical drugs such facilities should be subject to routine international random inspection. The national team should assist the international team in the process of verification.

In order for the verification to be effective it would be necessary that all relevant information be provided and to automatically control the production process with the help of monitoring and recording devices.

Hence, the international team can, by checking into the documentation and by visiting the plant, verify whether the corresponding synthesis is taking place in the plant.

Also the international team has a task to check whether all quantity of super-toxic lethal chemical: CWA and other chemical, were processed and used for research or for production drugs and other chemicals for peaceful purposes.

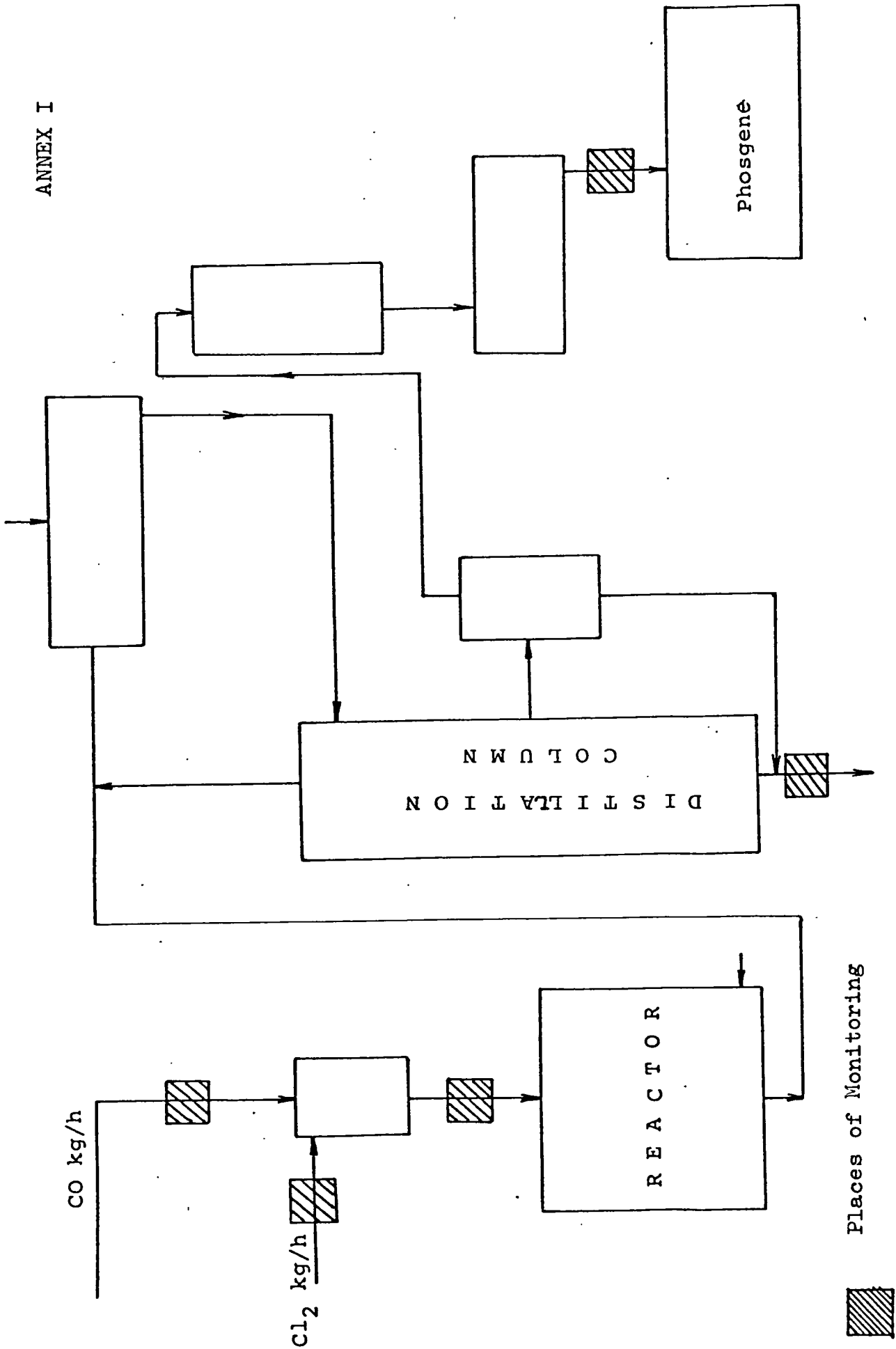
Verification of large-scale production facilities or industrial facilities

As these facilities are largely a part of the civil chemical industry, it would be necessary to ensure that their working continues unimpeded. They often produce toxic chemicals which are widely used in the chemical industry today. As a result, these chemicals are produced in large quantities. The capacity of a large-scale facility can vary from several thousand to a few tens of thousands of tonnes per year. These quantities, however, are most often processed into products intended for civilian purposes. Subsequently, only small quantities of dual-purpose chemicals are stored for the purpose of unimpeded production and are usually manufactured in the facilities intended for further processing. If these chemicals are processed in another plant or if they are exported, the international organization (Consultative Committee) should be notified.

The verification of such facilities should, we believe, be carried out by a national team, whose role and tasks were explained in the Yugoslav working paper CD/482.

If the report leaves doubt about the corresponding production process, whether in respect of quantity or quality, the international organization may decide to inspect the facility. Such an inspection should be based on a challenge inspection.

ANNEX I



Places of Monitoring



CONFERENCE ON DISARMAMENT

CD/614^{1/}
12 July 1985

Original: ENGLISH

LETTER DATED 12 JULY 1985 ADDRESSED TO THE PRESIDENT
OF THE CONFERENCE ON DISARMAMENT FROM THE CHARGE D'AFFAIRES A.I.
OF THE PERMANENT MISSION OF FINLAND, TRANSMITTING A DOCUMENT
ENTITLED "AIR MONITORING AS A MEANS FOR VERIFICATION OF CHEMICAL
DISARMAMENT; C.2. DEVELOPMENT AND EVALUATION OF BASIC
TECHNIQUES, PART I"

I have the honour to transmit to you a document
entitled "Air Monitoring as a Means for verification
of Chemical Disarmament; C.2. Development and
Evaluation of Basic Techniques, Part I". This study
represents a further contribution of the Government
of Finland to the work of the Committee on Disarmament
on chemical weapons.

I would appreciate if the study would be circulated
as an official CD document.

(Signed) Pekka Säilä
Chargé d'Affaires a.i.

^{1/} A limited distribution of this document in English only has been made
to the members of the Conference on Disarmament. Additional copies are
available from the Permanent Mission of Finland at Geneva.

CONFERENCE ON DISARMAMENT

CD/615
15 July 1985
ENGLISH
Original: RUSSIAN

LETTER DATED 15 JULY 1985 ADDRESSED TO THE PRESIDENT OF
THE CONFERENCE ON DISARMAMENT FROM THE REPRESENTATIVE OF
THE UNION OF SOVIET SOCIALIST REPUBLICS TRANSMITTING THE
TEXT OF THE TASS STATEMENT PUBLISHED ON 11 JULY 1985

I have the honour to transmit herewith a TASS statement issued on
11 July 1985 in connection with the decision by the United States Congress
to approve appropriations for the production of binary chemical weapons.

I would kindly request you to arrange to have this statement circulated
as an official document of the Conference on Disarmament.

(Signed) V. ISSRAELYAN

TASS STATEMENT

Recently the House of Representatives of the United States Congress, following the Senate, decided to appropriate funds for the production of binary chemical weapons. Although the starting date set for this production is 1987, and the decision is accompanied by some reservations, all of this does not change the substance of the matter: the United States is in practice approaching the point of adding to its military arsenal a new and even more dangerous type of barbarous weapon - a deadly nerve-gas mixture.

In the intentions of the strategy planners in Washington, the production of binary weapons should be part of a broad programme for the development of new weapons that are intended to ensure the military superiority of the United States. Not a day passes in Washington without the discussion and adoption of decisions relating to the development and deployment of new weapon systems: the MX and Midgetman intercontinental ballistic missiles, ballistic missile submarines, strategic aircraft and offensive space weapons.

The United States has taken the decisions leading to the production of binary weapons precisely at a time when negotiations are under way on the preparation of a convention on the prohibition and elimination of chemical weapons in the Conference on Disarmament at Geneva, with the support of the overwhelming majority of States. It is now clear why the United States is trying so persistently to lead the discussion of this pressing problem at the Conference into an impasse.

It is planned to station binary weapons above all in the territory of the Western European allies of the United States. As in the case of the Pershing-2 and long-range cruise missiles that have been deployed in a number of Western European States, here once again the insidiousness of Washington's intentions is displayed: it would like to remain on the sidelines, counting on exposing its allies' territory to a retaliatory strike. Binary weapons would thus be yet another source of great danger to the densely-populated countries of Western Europe.

The United States' project to begin production of binary chemical weapons must necessarily arouse serious alarm and indignation. The United States Government bears full responsibility for all consequences of this step. It is the direct duty of peoples not to allow this planned new crime against peace and mankind.

The Soviet Union firmly condemns the plans for the production and deployment of binary weapons. It consistently advocates the radical solution of the question of the prohibition and elimination of all types of chemical weapons, and reiterates its readiness actively to co-operate with all peace-loving States in achieving that goal.

PROGRESS REPORT TO THE CONFERENCE ON DISARMAMENT ON THE
TWENTIETH SESSION OF THE AD HOC GROUP OF SCIENTIFIC
EXPERTS TO CONSIDER INTERNATIONAL CO-OPERATIVE MEASURES
TO DETECT AND IDENTIFY SEISMIC EVENTS

1. The Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events, initially established in pursuance of the decision taken by the Conference of the Committee on Disarmament on 22 July 1976, held its twentieth formal session from 15 to 19 July 1985 in the Palais des Nations, Geneva, under the Chairmanship of Dr. Ola Dahlman of Sweden. This was the twelfth session of the Group convened under its new mandate by the decision of the Committee on Disarmament at its 48th meeting on 7 August 1979.
2. The Ad Hoc Group continues to be open to all Member States of the Conference on Disarmament as well as upon request to non-Member States. Accordingly, scientific experts and representatives of the following Member States of the Conference on Disarmament participated in the session: Australia, Belgium, Bulgaria, Canada, China, Czechoslovakia, Egypt, German Democratic Republic, Germany, Federal Republic of, Hungary, Italy, Japan, Netherlands, Poland, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland and the United States of America.
3. At their request and on the basis of previous invitations by the Committee on Disarmament, scientific experts from the following non-Member States of the Conference on Disarmament participated in the session: Denmark, Finland, New Zealand and Norway.
4. Under the current mandate of the Ad Hoc Group, information on national investigations related to the work of the Group has been presented by experts from Australia, Austria, Belgium, Bulgaria, Canada, Czechoslovakia, Denmark, Egypt, Finland, German Democratic Republic, Germany, Federal Republic of, Hungary, India, Indonesia, Islamic Republic of Iran, Italy, Japan, Netherlands, New Zealand, Norway, Peru, Poland, Romania, Sweden, Union of Soviet Socialist Republics, United Kingdom and United States of America.
5. During its tenth session, the Ad Hoc Group agreed to establish five study groups in order to achieve an appropriate compilation, summarization and assessment of the experience acquired through national investigations and co-operative studies in areas relevant to its work. These open-ended study groups each deal with a specific issue, and are each headed by a convenor and a co-convenor, as follows:
 1. Seismological stations and station networks: Dr. Basham (Canada), Dr. Schneider (German Democratic Republic)
 2. Data to be regularly exchanged (Level I data): Dr. Harjes (Germany, Federal Republic of), Dr. Fiedler (Czechoslovakia)

3. Format and procedures for the exchange of Level I data through WMO/GTS: Dr. McGregor (Australia), Dr. Mori (Japan)
4. Format and procedures for the exchange of Level II data: Dr. Husebye (Norway), Dr. Christoskov (Bulgaria)
5. Procedures to be used at international data centres: Dr. Johansson (Sweden), Dr. Alewine (United States of America).

6. During its eighteenth session, the Ad Hoc Group worked out and agreed on detailed procedures and time schedule for a technical test concerning the exchange and analysis of Level I data using the WMO/GTS (document CD/534). This technical test was the first one conducted making regular use of the WMO/GTS. It further developed procedures for the use of the WMO/GTS for seismic data exchange, and procedures related to the use of the WMO/GTS at envisaged international data centres. The purposes of this technical test were:

- to develop and test procedures (with the WMO) for the regular transmission of Level I data from temporary national facilities to experimental international data centres (EIDCs). These were established during the technical test to provide the services of both the national facilities and the IDCs first envisaged in CCD/558;
- to transmit bulletins from EIDCs to participating temporary national facilities using the WMO/GTS;
- to test procedures for retransmission of Level I data messages over the WMO/GTS;
- to provide an opportunity for testing procedures for extracting Level I parameters at seismic stations;
- to develop and test procedures for transmission of Level I parameters to temporary national facilities;
- to test proposed procedures at EIDCs for receipt and archiving of Level I data and for compilation and distribution over the WMO/GTS of event bulletins and parameters using Level I data.

7. The technical test covered seismic Level I data for the period from 00.00 Universal Co-ordinated Time (UTC) 15 October to 24.00 UTC 14 December 1984. The preparation and transmission of event bulletins from EIDCs continued until 15 January 1985. The time period from 15 October to 26 October 1984 was designated as a preparatory phase to establish reliable communications.

8. In all, 76 seismograph stations in 36 countries contributed seismic Level I data to the technical test. For organizational and technical reasons, however, not all of these countries provided and received data for the entire time period.

9. Experimental international data centres were operated throughout the time period of the test at Moscow, Stockholm and Washington.

10. The technical test was co-ordinated overall by Dr. Peter McGregor, Australia, who carried out this important task with great skill and dedication.

11. During the technical test the Ad Hoc Group has enjoyed an excellent co-operation with the WMO as well as with the national meteorological and seismological institutions in participating countries.

12. The Ad Hoc Group reviewed a draft report to the Conference on Disarmament on the results of the test. This draft report had been compiled by the Group's Scientific Secretary based on contributions from Study Group Convenors. A number of national investigations containing results of comprehensive analyses of the large volumes of data generated during the technical test formed the basis for this material. In reviewing the draft, the Group conducted preliminary discussions on the technical results of the test and how they related to the stated objectives.

13. The Ad Hoc Group agreed that the objectives of the technical test were successfully fulfilled. The technical test has provided extremely valuable experience and technical information, previously unavailable, on the topics given in paragraph 6.

14. The Ad Hoc Group also discussed the schedule for its further work. It envisages submitting its report to the Conference on Disarmament on the technical test during the first part of the 1986 session, on the understanding that a complete draft be distributed to the members of the Ad Hoc Group by 1 December 1985.

15. The Ad Hoc Group suggests that its next session, subject to approval by the Conference on Disarmament, should be convened from 10 to 21 March 1986, in Geneva.

CONFERENCE ON DISARMAMENT

CD/617
22 July 1985

Original: ENGLISH

LETTER DATED 19 JULY 1985 ADDRESSED TO THE PRESIDENT OF THE CONFERENCE ON DISARMAMENT FROM THE CHARGE D'AFFAIRES A.I. OF THE PERMANENT MISSION OF THE ISLAMIC REPUBLIC OF IRAN TRANSMITTING THE "REPORT OF THE SPECIALISTS APPOINTED BY THE SECRETARY-GENERAL TO INVESTIGATE ALLEGATIONS BY THE ISLAMIC REPUBLIC OF IRAN CONCERNING THE USE OF CHEMICAL WEAPONS" 1/

I have the honour to refer to the question of the effective verification of the use of chemical weapons which is one of the most central issues concerning the creation and, even more importantly, the viability of a future chemical weapons convention.

In considering this issue the Conference should not fail to take advantage of the invaluable experiences gained by the international community through the reports recently prepared following investigations of the alleged use of chemical weapons by Iraq in the course of the current Persian Gulf conflict.

The "Report of the Specialists appointed by the Secretary-General to investigate allegations by the Islamic Republic of Iran concerning the use of chemical weapons", Security Council document S/16433 of 26 March 1984 as a unique reflection of an unprecedented yet successful fact-finding mission carried out by the United Nations in this field is of great value.

In view of this, the delegation of the Islamic Republic of Iran finds it appropriate to distribute in the Conference copies of the above-mentioned report of the United Nations specialists, as annexed to this letter, in order to contribute to the work of the Conference, particularly in the context of the endeavours pursued by the Ad Hoc Committee on Chemical Weapons.

Please regard this letter as an official document of the Conference and make arrangements accordingly for its distribution. Fifty copies of this annex are forwarded to you along with this letter for distribution among the members and observer delegations of the Conference on Disarmament.

(Signed) Farhad SHAHABI SIRJANI
Charge d'affaires a.i.

1/ A limited distribution of this document in English only has been made available to the Conference on Disarmament. Additional copies are available from the Permanent Mission of the Islamic Republic of Iran.

GE.85-63054

CANADA

Working Paper

Survey of International Law Relevant to
Arms Control and Outer Space

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Preface

For a number of years prior to 1985, the Conference on Disarmament (CD) and its predecessor organizations have recognized the importance of outer space. It was, however, only on 29 March 1985 that the CD succeeded in reaching agreement on a mandate for an ad hoc Committee on the Prevention of an Arms Race in Outer Space. This development was welcomed by Canada and other member nations as a first step toward an organized examination of the subject. This process is in accordance with the United Nations General Assembly resolution which was adopted without dissent during its 39th session on December 12, 1984 and which called upon the CD to consider the question of preventing an arms race in outer space as a matter of priority. The mandate now adopted by the CD is a realistic one. It is neither narrow nor restricted but permits the CD to begin some action and undertake concrete work almost immediately.

The ad hoc Committee on the Prevention of an Arms Race in Outer Space established under the mandate, is "to examine, as a first step at this stage, through substantive and general consideration, issues relevant to the prevention of an arms race in outer space". In the process, it should take into account all existing agreements, existing proposals and future initiatives, then report on the progress of its work to the Conference on Disarmament in August, 1985.

From the Canadian perspective, the creation of the ad hoc Committee on outer space is in line with Canada's expressed policy and constitutes a significant step forward in coming to grips with the subject. The mandate of the ad hoc Committee both complements and accurately reflects the realities concerning the bilateral negotiations already underway between the United States and the Soviet Union in Geneva. It neither undermines, prejudices nor in any way interferes with those negotiations and this fact is considered by Canada to be absolutely central to the successful process of both sets of deliberations.

On 26 August 1982, Canada submitted its first substantive working paper to the CD on the outer space issue. That document entitled "Arms Control and Outer Space" (CD/320) undertook to discuss generally the subject of arms control and outer space in terms of stabilizing and destabilizing characteristics. With the establishment

of an ad hoc Committee to focus in more detail, Canada is prepared to reinforce its efforts and to participate actively and effectively in developing an understanding and consensus for further work relating to the subject of preventing an arms race in outer space.

This working paper is meant to facilitate consideration of this area by the CD by providing a basis for examining its legal context. In general, as a review of international law relating to arms control and outer space, it presents a broad interpretation of a variety of views concerning the significance and application of some of the existing treaties. It does not purport to provide a Canadian government position on any issue. Instead, in terms of the CD mandate relating to the prevention of an arms race in outer space, its objective is to provide a rational basis for discussion from which the ad hoc Committee might wish to develop its approach to the subject. It will be apparent throughout this paper that different interpretations may emerge due to the lack of consensus regarding terminology and definitions relating to the outer space.

I. Introduction

Generally speaking there are four sources of international law as outlined by Article 38(1) of the Statute of the International Court of Justice.¹ These are:

- (a) international conventions, whether general or particular, establishing rules expressly recognized by the contracting states;
- (b) international custom, as evidence of a general practice accepted as law;
- (c) the general principles of law recognized by civilized nations;
- (d) ... judicial decisions and the teachings of the most highly qualified publicists of various nations, as subsidiary means for the determination of rules of law.

This paper will limit its consideration to two categories. First, international conventions and treaties relevant to outer space will be reviewed. Treaties express the intention of the parties to create binding obligations under international law. They may also

reflect general principles of law and the obligations undertaken as part of a treaty may obtain broader acceptance so as to become a part of customary law.

Second, this paper will focus on UNGA resolutions some of which may reflect existing customary law or at least be indicative of the directions in which that law is evolving.

Comments by legal analysts have been included in the text where deemed appropriate.

II. International Agreements

Any consideration of international treaty law should be undertaken on the basis of the principles enumerated in the Vienna Convention on the Law of Treaties.²

Article 31 of this Convention provides the following general rule of interpretation:

1. A treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.
2. The context for the purpose of the interpretation of a treaty shall comprise, in addition to the text, including its preamble and annexes:
 - (a) any agreement relating to the treaty which was made between all the parties in connection with the conclusion of the treaty;
 - (b) any instrument which was made by one or more parties in connection with the conclusion of the treaty and accepted by the other parties as an instrument related to the treaty.
3. There shall be taken into account, together with the contexts:
 - (a) any subsequent agreement between the parties regarding the interpretation of the treaty or the application of its provisions;
 - (b) any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation;

(c) any relevant rules of international law applicable in the relations between the parties.

4. A special meaning shall be given to a term if it is established that the parties so intended.

The discussion of treaties which follows is arranged chronologically by the date of the agreement in question. It should be noted that several treaties are covered which might seem at first glance to be irrelevant to the subject of arms control and outer space. These agreements are included simply because some of their provisions (especially those regarding verification) or the circumstances surrounding their negotiation may shed light on developments respecting arms control and outer space.

(i) The Charter of the United Nations (1945)³

The UN Charter has considerable relevance to the subject of arms control and outer space. It is explicitly mentioned in several treaties which deal directly with outer space including the 1967 Outer Space Treaty where parties agree to carry on their activities relating to the exploration and use of outer space "in accordance with international law, including the Charter of the United Nations ..." (Article III; see also the Preamble). Similarly, the Moon Treaty mentions the Charter (Articles II and IV) as does the Environmental Modification Treaty (Preamble and Article V).

Particularly relevant in the context is one of the stated purposes of the UN:

1. To maintain international peace and security, and to that end: to take effective collective measures for the prevention and removal of threats to the peace, and for the suppression of acts of aggression or other breaches of the peace, and to bring about by peaceful means, and in conformity with the principles of justice and international law, adjustment or settlement of international disputes or situations which might lead to a breach of the peace; (Article 1)

Also important is the Preamble which states that the peoples of the United Nations will ensure that "by

acceptance of principles and the institution of methods, that armed force shall not be used, save in the common interest".

States are also inter alia obligated to settle disputes peacefully and refrain from the threat or use of force under Article 2:

The Organization and its members, in pursuit of the Purposes stated in Article 1, shall act in accordance with the following Principles.

1. The Organization is based on the principle of the sovereign equality of all its Members.
2. All Members, in order to ensure to all of them the rights and benefits resulting from membership, shall fulfil in good faith the obligations assumed by them in accordance with the present Charter.
3. All Members shall settle their international disputes by peaceful means in such a manner that international peace and security, and justice, are not endangered.
4. All members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any other manner inconsistent with the purposes of the United Nations....

Such obligations would seem to apply also to the activities of states in outer space, especially in view of the provisions of the Outer Space Treaty and other treaties mentioned above.

An important proviso to these obligations under the Charter is contained in Article 51 which states:

Nothing in the present Charter shall impair the inherent right of individual or collective self-defence if an armed attack occurs against a Member of the United Nations, until the Security Council has taken measures necessary to maintain international peace and security. Measures taken by members in the exercise of this right of self-defence shall be immediately reported to the Security Council and shall not in any way affect

the authority and responsibility of the Security Council under the present Charter to take at any time such action as it deems necessary in order to maintain or restore international peace and security.

(ii) Antarctic Treaty (1959)⁴

During the International Geophysical Year (IGY) of 1957⁵ the international scientific community conducted a number of studies of man's environment - the earth, the oceans, the atmosphere and outer space. The guidelines for the IGY contained several ideas which were later incorporated in the Antarctic Treaty of 1959, and some of these basic provisions served as precedents for later treaties particularly the 1967 Outer Space Treaty, the 1967 Treaty of Tlatelolco, the 1971 Seabed Treaty, and the 1979 Moon Treaty.

Two of the main purposes of the Antarctic Treaty were to ensure continuation of scientific cooperation and to avoid the militarization of the continent. In regard to the latter, the suitability of Antarctica for nuclear tests and the testing of other military equipment provided a strong incentive to prohibit the military use of Antarctica.

The preamble to the Antarctic Treaty recognized "that it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord" indicating that the parties intended to create a legal regime for this area which would ensure peace on the continent and facilitate international cooperation.

In its operative part, the Treaty seeks to preserve a non-militarized status of the Antarctic by prescribing in Article I(1) that it shall be used "for peaceful purposes only" and prohibits "inter alia any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military manoeuvres, as well as the testing of any type of weapons".⁶ It is interesting to note that certain terms, such as "peaceful purposes", are not defined in the treaty.⁷

The Treaty, according to paragraph 2 of Article I, "shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purposes". This provision is said to have been

included in recognition of the importance of the support rendered, to scientific activities by naval vessels and personnel.⁸

The extent of the freedom of scientific investigation, as established in Article II of the Treaty, is set out in Article III. Freedom of scientific investigation is provided for to the extent to which it was actually exercised during the IGY.⁹ Furthermore, one of its important elements is that of international cooperation.¹⁰ The parties to the Treaty agree that to the greatest extent feasible and practicable, exchanges shall take place concerning plans for scientific programmes, or scientific personnel between expeditions and stations, and of scientific observations and results. Provision is also made for close cooperation with the specialized agencies of the United Nations and other international organizations having scientific or technical interest in Antarctica (Article II(2)).

Article V prohibits "any nuclear explosions in Antarctica and the disposal there of radioactive waste material".¹¹

In order to promote the objectives and to ensure the observance of the Treaty's provisions, the principle of open inspection was established in Article VII of the Treaty.¹² Under paragraph 3 of Article VII, all areas of Antarctica, including all stations, installations and equipment shall be open at all times to inspection by any observers designated by state parties. Each of these observers shall have complete freedom of access at any time to any or all areas of Antarctica. Aerial observation is also permitted. In order to facilitate observation, information is exchanged between the parties as to expeditions to and within Antarctica, on all stations therein and any military personnel or equipment intended to be introduced into Antarctica (Article IX(1)). No sanctions are provided for non-compliance with the Treaty's provisions. Disputes about interpretation of the Treaty are to be dealt with by consultations. If a dispute remains unresolved, it may be taken to the International Court of Justice (Article XI).

Article IX of the Treaty contains important elements for the joint administration of Antarctica. In particular, representatives of contracting parties so entitled shall meet at suitable intervals for the purpose of exchanging information and for consultation on matters of common interest pertaining to Antarctica; and for

formulating and considering, as well as recommending to their governments, measures to further the principles and objectives of the Treaty. Article XII provides for a review conference thirty years after the Treaty's coming into force.

Prior to the beginning of international cooperation for scientific research, a number of states had already made claims of sovereignty over part of Antarctica. Article IV of the Treaty basically "freezes" the claims to sovereignty and jurisdiction of interested states. Under this provision, the Treaty does not have the effect of a renunciation by any contracting party of previously asserted rights or claims to territorial sovereignty. Furthermore, no new claims or enlargement of any existing claims shall be asserted while the Treaty is in force (Article IV(2)).

Concepts embodied in the Antarctic Treaty, such as the use of this area for peaceful purposes only, the freedom of scientific investigation, the promotion of international cooperation and the exchange of information and scientific personnel constitute examples of provisions which may be of relevance to the subject of arms control and outer space. The Antarctic Treaty is an example of the contribution that international law can make in ensuring a safer world.¹³

(iii) The Partial Test Ban Treaty (1963)

Concern for radioactive fallout caused by nuclear testing was one of the strongest motivating forces behind the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water.¹⁴

It developed between 1958 and 1962, with negotiations eventually being conducted in the Eighteen Nation Disarmament Committee (ENDC). Lack of progress in this forum led to private negotiations which resulted in the Treaty. The ENDC and its successors have considered but have not concluded an agreement to ban all nuclear tests.

The direct effect of paragraphs 1 and 2 of Article I is such that it is illegal to carry out a nuclear explosion in outer space:

1. Each of the Parties to this Treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other

nuclear explosion, at any place under its jurisdiction or control;

(a) in the atmosphere; beyond its limits, including outer space;...

2. Each of the Parties to this Treaty undertakes furthermore to refrain from causing, encouraging, or in any way participating in, the carrying out of any nuclear weapon test explosion, or any other nuclear explosion anywhere which would take place in any of the environments described, or have the effect referred to, in paragraph 1 of this Article.

(iv) Outer Space Treaty (1967)

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space including the Moon and Other Celestial Bodies,¹⁵ commonly known as the Outer Space Treaty, is regarded as the cornerstone international space law convention. As is evident from its full title, the Treaty establishes a basic legal framework for general space exploration and utilization. Moreover, it marks an important step in controlling certain, though not all, arms in outer space.

Being the first international convention directly relating to an environment regulated by, at best, nebulous customary international law principles, its significance cannot be overestimated. Its adoption brought about substantive changes in the legal regime of outer space. What before had merely been a set of non-binding guidelines now became legal obligations.

Since the Treaty holds a central position within the legal framework governing all activities carried out in space, it is necessary to examine its provisions closely. Three general themes emerge from such an examination: freedom of exploration and use, peaceful use and cooperation and international responsibility of states for their activities in outer space.

In the operative part of the Treaty, Article I reiterates the primary interests of the international community:

The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests

of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

Outer Space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

There shall be freedom of scientific investigation in outer space, including the moon and other celestial bodies, and States shall facilitate and encourage international cooperation in such investigation.

This Article establishes a basic principle of space law: space shall be free for exploration and use by all states on the basis of equality.

According to Article II, outer space is not subject to national appropriation by claims of sovereignty, by means of use or occupation, or by any other means. This Article reflects the notion of res communis already granted substantial recognition by customary international law. Article III obliges states to undertake space activities "in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding".

The primacy of the common interest of all nations¹⁶ is stressed again in Article IX of the Outer Space Treaty which states that parties shall be guided by the principle of cooperation and mutual assistance in the exploration and use of outer space, and shall conduct all their activities with due regard to the corresponding interests of all other parties to the Treaty. It is worthy of note that in the first three articles of the operative part of the Outer Space Treaty, in which the guiding principles governing space activities have been laid down, no mention of the use of the whole of outer space exclusively for peaceful purposes has been made.¹⁷ It is only with respect to the moon and other celestial bodies that this concept has been accepted (Article IV(2)).

Article IV contains the only provision of the Outer Space Treaty addressed specifically to military activities and reads as follows:

States Parties to the Treaty undertake not to place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited.

The first paragraph of this article codifies the policy set forth in a bilateral pledge by the United States and the Soviet Union, later unanimously adopted as a resolution of the United Nations General Assembly.¹⁸ Within its admitted limits it contributed affirmatively to the stabilization of international relations through the imposition of some restraints on the military use of the space environment.¹⁹ It also expands the prohibition against nuclear tests in outer space contained in the Partial Test Ban Treaty, to encompass any other kind of weapons of mass destruction.

The second paragraph of Article IV is one of the most controversial provisions of the Treaty and has often been cited in support of the claim that the Treaty forbids only those military activities that are enumerated in the above-mentioned article.²⁰ An argument has been advanced that Article IV, in conjunction with other provisions of the Treaty, imposes "complete demilitarization of outer space".²¹ However, the negotiating history of the Treaty, its text and the practice of states would not seem to support this view.

To verify compliance with the provisions of the Outer Space Treaty, Article XII provides for inspection "on the basis of reciprocity" of all stations,

installations and equipment on the moon or other celestial bodies. Advance notice of inspection is required to ensure safety and to avoid interference with the operations of the facility to be visited. This provision for inspections does not, however, apply to objects in earth orbit. Observation of launches and flights of spacecraft on a voluntary basis is also allowed for by Article X. Article XI, which requires states to inform the UN Secretary General, the public and the scientific community "to the greatest extent feasible and practicable, of the nature, conduct, locations and results" of space activities, also has a limited role in the context of verification.

Concerning anti-satellite (ASAT) weapons Article IV of the Outer Space Treaty, read alone, makes certain legal conclusions clear. First, weapons systems of any kind including conventional weapon systems cannot be lawfully employed on the moon or other celestial bodies.²² Second, the precise language of Article IV is such that ASATs "would not be prevented from being placed in outer space, per se",²³ since there is no specific stipulation in Article IV that space shall be used "exclusively for peaceful purposes" and ASATs are not prima facie weapons of mass destruction. Moreover, the negotiations between the space powers on this matter³¹ suggest that they do not regard the terms of the Outer Space Treaty, as prohibiting the emplacement of anti-satellite devices in outer space. This attitude is further reinforced by recent Soviet proposals to ban all weapons in space. Thus, it would appear that the term "weapon of mass destruction" does not cover the emplacement in outer space of non-nuclear ASAT weapons. The same analysis is likely to apply to laser and particle-beam weapon systems with one reservation: the incipient nature of such systems makes it difficult to conclude whether such weapon systems would be for the purpose of mass destruction. This would probably depend on the type of system and its design objectives. Fractional orbital bombardment missiles (FOBS), although clearly weapons of mass destruction, may also not be prohibited by the Outer Space Treaty because they are in "outer space" (as yet undefined in international law) for less than one full orbit around the earth. SALT II, however, does include a provision prohibiting new FOBS systems.

It is worth mentioning that the Outer Space Treaty is not, in fact, an arms control treaty but was in large measure negotiated in COPUOS. COPUOS does not have

a mandate specifically to negotiate matters concerning arms control. That is the specific responsibility of the CD. It is recognized, however, that the arms control and peaceful use aspects of the outer space issue are closely related.

(v) The Treaty of Tlatelolco (1967)

The parties to the Treaty for the Prohibition of Nuclear Weapons in Latin America²⁴ agree to use nuclear materials under their jurisdiction exclusively for peaceful purposes and to prevent on their territories the testing, use, manufacture, production, acquisition, receipt, storage, installation, deployment or any form of possession of nuclear weapons. They also agree to refrain from engaging in or participating in the testing, use, manufacture, production, possession or control of nuclear weapons (Article I). In essence, the Treaty establishes a nuclear weapons free zone in Latin America.

The safeguards system of the International Atomic Energy Agency applies to peaceful nuclear activities of parties as a control mechanism and for verification purposes (Article XII). In addition, the Convention establishes the Agency for the Prohibition of Nuclear Weapons in Latin America to ensure, among other things, compliance with Treaty provisions (Article VII). The Treaty is noteworthy as representing the first agreement on arms limitation to create an effective regional system of control under a permanent supervisory organ. Specifically, the Agency and the IAEA have the authority to verify that devices and facilities intended for peaceful uses of nuclear energy are not used to test or manufacture nuclear weapons and that explosions for peaceful purposes are compatible with the Treaty. Methods of verification include inspections (Article XVI). Measures are prescribed in the event of violation including referral of the matter to the OAS and UN (Article XX). The Agency is also empowered to enter into relations with any international organization or body, including any future body established to supervise disarmament or measures for the control of armaments in any part of the world (Article XIX).

The Treaty might be seen to serve as an initial model of regional cooperation for the control of arms. The verification provisions also provide a precedent for international control organizations.

(vi) Rescue and Return Agreement (1968)

The Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space²⁵ as its title suggests provides for the tendering of assistance and the rescue of astronauts in distress whether on sovereign territory or from areas outside of state jurisdiction.²⁶

(vii) The Non-Proliferation Treaty (1968)²⁷

This Treaty was negotiated and drafted by the ENDC pursuant to the 1965 General Assembly Resolution 2028 (XX) requesting the ENDC to give urgent consideration to the problem of nuclear weapons proliferation.

Article I of the Non-Proliferation Treaty prohibits the transfer, from a nuclear-weapon state "to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly." It also requires nuclear weapon states "not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices".

This is the active prohibition. The corollary is found in Article II which prohibits the corresponding activities on the part of the non-nuclear receiving state.

Article III provides for verification using safeguards established by the International Atomic Energy Agency. The IAEA inspectors have the authority to conduct regular on-site inspections of nuclear facilities coming under the NPT regime. The NPT, therefore, can be said to serve as a precedent for the establishment of an international body empowered to monitor compliance with a multilateral convention dealing with a specific type of weapon.

(viii) The Seabed Treaty (1971)²⁸

This Treaty prohibits emplacing on the seabed and the ocean floor, and in the subsoil thereof beyond the outer limit of a coastal zone, any nuclear weapons or any other types of weapons of mass destruction as well as structures, launching installations or any other facilities especially designed for storing, testing or using such weapons (Article I).

Article III, paragraph 1 of the Treaty states that in order to ensure compliance, each state party has the right to verify, through observation, the activities of other parties on the seabed provided only that this observation does not interfere with such activities. Such observation can be conducted by the parties through the use of their own means, with the assistance of other parties or through appropriate international procedures within the framework of the United Nations and in accordance with its Charter. Should a state be dissatisfied with its inspection and reasonable doubts remain concerning the fulfillment of obligations assumed under the Treaty, the parties shall consult with a view to removing such doubts (Article III (2)). If doubts still persist, the state questioning compliance may notify the other parties to the Treaty with a view to co-operating on further procedures for verification including appropriate inspection of installations (Article III (3)). Finally, if satisfaction is still lacking, the state may refer the matter to the UN Security Council which is empowered to take any action in accordance with the Charter (Article III (4)). The Final Declaration of the Second Review Conference of the parties to the Seabed Treaty states that paragraphs (2), (3) and (5) of Article III include the right of parties to resort to various international consultative procedures, such as ad hoc consultative groups of experts.

Like the Antarctic Treaty, the Treaty of Tlatelolco and the Outer Space Treaty, the Seabed Treaty prevents the introduction of nuclear weapons to a new region of the earth's environment.

- (ix) Agreement on Measures to Reduce the Risk of Outbreak
of Nuclear War (1971)²⁹, Agreement on Measures to
Improve the Direct Communications Link (1971)³⁰ and
Agreement on the Prevention of Nuclear War (1973)³¹

In the Prevention of Nuclear War Agreement each side undertakes to act in a manner so as "to prevent the development of situations capable of causing a dangerous exacerbation of their relations, as to avoid military confrontations and as to exclude the outbreak of nuclear war between them and between either of [them] and other countries" (Article I). This is further extended by Article II which requires the parties to refrain from the

threat or use of force against the other or its allies. In a crisis threatening nuclear war the parties agree to hold consultations.

The Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War requires the parties, inter alia, to notify each other immediately of signs of interference with their early warning systems or related communications facilities if such occurrences threaten nuclear war (Article III). There is, in this provision, a recognition that interference with early warning systems (including satellites) could risk the outbreak of nuclear war. Since the parties have agreed in the Prevention of Nuclear War Agreement not to create situations or use force which would endanger international peace and security or cause a dangerous exacerbation of their relations, they have an implied understanding of the need to avoid interfering with early warning satellites.

The 1971 Agreement on Measures to Improve the Direct Communication Link requires the establishment of two additional communications circuits between the superpowers, using satellite communications systems (Article I). Furthermore, "each Party confirms its intention to take all possible measures to ensure the continuous and reliable operation of the communication circuits ..." (Article II). These provisions therefore, to prohibit interference with communications satellites involved in the Direct Communication Link.

(x) Convention on International Liability for Damage Caused by Space Objects (1972)³²

This Convention is primarily intended to ensure prompt and equitable compensation for victims of damage caused by space objects. It establishes a set of rules for determining the source and measure of liability for damage occurring on earth, in outer space and in airspace. Specific procedures are envisaged for third party arbitration in cases of disagreement on responsibility or payment of damages.

Different degrees of liability apply depending on the location of the damage resulting from space activities. If the damage occurs on the earth's surface or to aircraft in flight then the launching state is absolutely liable (Article II). If, however, the damage is to another space object, then liability only attaches if the damage is due to the launching state's fault (Article III).

While the Convention is not directly relevant to arms control and outer space, it does reinforce the view that states are legally responsible for their activities, presumably including military activities, in outer space. Moreover, should the military activities of a state in outer space cause damage to third parties, presumably civil liability for those damages might follow.

(xi) Biological Weapons Convention (1972)³³

One of the few truly disarmament agreements, this Convention prohibits the development, production, stockpiling and acquisition of biological warfare agents and weapons including toxins. It also requires the destruction or diversion to peaceful uses of existing stocks.

Only limited provisions are incorporated with regard to handling compliance problems. The parties agree to consult and cooperate with each other to resolve disputes about implementation (Article V). This may take place through appropriate international procedures within the framework of the United Nations. Complaints regarding violations of the treaty can be lodged with the UN Security Council (Article VI) and parties agree to cooperate with any Security Council investigation. Recent difficulties in resolving allegations of the use of chemical and/or toxin agents in South-East Asia and elsewhere illustrate the consequences of the lack of adequate agreed international verification of compliance procedures in such a treaty.

(xii) Anti-Ballistic Missile Treaty (1972)³⁴

This Treaty between the USA and USSR prohibits the deployment of anti-ballistic missile (ABM) defences except for limited systems to protect each national capital and one other area (Article I and III). The 1974 Protocol to the Treaty restricts each side to one site only. Moreover, while the Treaty permits the development and testing of fixed land-based ABM systems at selected test sites, the parties undertake "not to develop, test or deploy ABM systems or components which are sea-based, air-based, space-based, or mobile land-based" (Article V (1), emphasis added). It can be noted that research is not expressly prohibited by the Treaty.

Verification of compliance with the ABM Treaty is to be provided by the use of "national technical means... in a manner consistent with generally recognized principles of international law" (Article XII (1)). Each party also agrees not to interfere with the national technical means of the other when used in accordance with Article XII (1). Furthermore, the use of deliberate concealment measures to impede verification by national technical means is prohibited (Article XII (2) and (3)). This provision against non-interference with national technical means has direct relevance to the law of outer space because one of the primary components of national technical means are reconnaissance satellites. In essence this provision reinforces the legitimacy of such satellite activities.

A Standing Consultative Commission is created to deal with compliance issues and other questions relating to the implementation of the Treaty (Article XIII).

(xiii) SALT I (1972)³⁵ and SALT II (1979)³⁶

These agreements limit the number of strategic delivery vehicles that the superpowers may deploy. Only one provision of these agreements directly relates to outer space. Article IX (1)(C) of SALT II prohibits the development, testing or deployment of: "systems for placing into Earth orbit nuclear weapons or any other kind of weapons of mass destruction, including fractional orbital missiles". A common understanding to this provision states that it does not require the dismantling of any existing launchers. This provision, however, would seem to reaffirm and extends for these two states the applicability of the restrictions regarding nuclear weapons incorporated into Article IV of the Outer Space Treaty.

The other features of these agreements that are of most interest here, are those relating to verification. SALT I incorporates the same provision (Article V) regarding use of national technical means as that found in the ABM Treaty (Article XII). Compliance questions are referred to the same Standing Consultative Commission (Article VI).

SALT II also relies for verification on national technical means to be used in accordance with generally recognized principles of international law (Article XV (1)). As in SALT I and the ABM Treaty each party undertakes not to interfere with the other's national technical means (Article XV (2)) and not to use deliberate concealment measures to impede verification by national technical means (Article XV (3)). More precise definitions of concealment are provided in the form of Agreed Statements and Common Understandings. The use of design requirements such as "functionally related observable differences" to distinguish between weapons systems also facilitates verification. As was the case for the ABM Treaty and SALT I, these provisions relating to verification underscores the legitimacy of the use of military reconnaissance satellites which are a major element of national technical means of arms control and disarmament verification.

It is worth noting that recent events have underlined the limitations of national technical means when used alone for verification of strategic arms limits and have emphasized the need for additional effective methods of handling compliance questions.

SALT I expired in 1977 though both sides agreed to abide by its terms after that time. SALT II expires 31 December 1985. Though never ratified, both parties agreed to abide by the terms of SALT II on a reciprocal basis.

(xiv) The Threshold Test Ban Treaty (1974)³⁷ and the Peaceful Nuclear Explosions Treaty (1976)³⁸

These two treaties are bilateral ones between the USA and the USSR. The Threshold Test Ban Treaty prohibits underground nuclear weapons tests exceeding 150 kt (Article I) and limits tests to designated test sites (Para. 1 of Protocol).

Verification, as under the ABM Treaty and SALT Treaties, is to be conducted by each side's national technical means used in a way consistent with international law (Article II). Each party again agrees not to interfere with the national technical means of the other. These national technical means include satellites as well as ground-based seismographic instruments.

In addition, the parties agree to consult about implementation. Noteworthy also is the exchange of data provisions in the Protocol relating to test site coordinates, geology, and test details. This Treaty was not ratified and no data exchange occurred. The parties did however state that they would abide by the 150 kt limit, on a reciprocal basis.

The Peaceful Nuclear Explosions Treaty is intended to complement the Threshold Test Ban Treaty by establishing a regime to govern underground nuclear explosions for peaceful purposes which by definition are those conducted outside test sites specified under the latter treaty. It limits any single peaceful nuclear explosion to 150 kt on a reciprocal basis. Any group of peaceful nuclear explosions is limited to 1500 kt. In the case of a group explosion, observers are to be invited on-site and they can bring their own monitoring equipment. Special detailed procedures for the shipment of this equipment are outlined. Other provisions for inspections are given regarding group explosions and individual explosions of different sizes. For explosions below 150 kt, national technical means of verification are relied upon, together with detailed data on the explosion provided by the party conducting it. The amount of information to be provided varies with the yield of the blast. A joint Consultative Commission is to be established to facilitate exchange of information and verification. Detailed procedures for the conduct of inspections are spelled out in a Protocol.

As with the Threshold Test Ban Treaty, the Peaceful Nuclear Explosions Treaty has not been ratified. The Treaty is significant because it involves on-site inspections that would take place at military-related sites on the territory of each superpower. Moreover, the two Treaties because they refer to non-interference with national technical means, again reinforce the legitimacy of military reconnaissance satellites as verification systems in the arms control and disarmament process.

(xv) The Registration Convention (1975)

The Convention on Registration of Objects Launched into Outer Space³⁹ entered into force on 13 September 1976. The Treaty establishes a mandatory and uniform registration system for objects launched into outer space. It provides for a general registry which is kept by the United Nations Secretary General and which is

publicly accessible. The Convention also provides a uniform format for information furnished by launching states.

The Treaty is based on the voluntary system established by General Assembly Resolution 1721 of 1961.⁴⁰ Under the voluntary system there was, however, no delineation of what details should be provided. Consequently, the information furnished by countries was not uniform and was not reported promptly and on a regular basis.

The Registration Convention is a reflection of the general principles established by the Outer Space Treaty and elaborated through the Rescue Agreement and Liability Convention. While the other treaties do not refer to a central registry system, the Outer Space Treaty does contemplate national registries.⁴¹

Three reasons have been posited for the establishment of a central registry: effective management of traffic, enforcement of safety standards, and imputation of liability for damage.⁴² While the central registry is the most significant feature of the Treaty, it fulfills several other important objectives. Launching countries must maintain a national registry (Article II). Article IV of the Registration Convention requires mandatory reporting to the Secretary-General of the United Nations of information on a number of data, such as the date and location of the launch, changes in orbital parameters after the launch, and the recovery date of the spacecraft. States are not obliged to disclose the specific function of the satellite, but only the "general function of the space objects" (Article 1(e)). Furthermore, the Registration Convention does not require a launching state to provide appropriate identification markings for its spacecraft and its component parts.⁴³

It is worthy of note that, notwithstanding the fact that over half of the satellites launched serve military purposes,⁴⁴ not one of the launchings registered has ever been described as having a military function.

(xvi) Environmental Modification Convention (1977)

The Environmental Modification Convention⁴⁵ as its title suggests aims at prohibiting the hostile use of potentially disastrous environmental modification techniques. This Convention is relevant to outer space

because of the potential of space science and technology for use in environmental modification either for peaceful or hostile uses. The dual-purpose nature of these technologies is explicitly referred to in the Preamble of the Convention which recognizes that the use of such techniques for peaceful purposes could "contribute to the preservation and improvement of the environment for the benefit of present and future generations", while their military or any other hostile application "could have effects extremely harmful to human welfare".

The key provision of the Convention is contained in Article I (1) which prohibits "military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party". Environmental modification techniques are defined as those which can be used "for changing - through the deliberate manipulations of natural processes - the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere, and atmosphere, or of outer space" (Article II, emphasis added). The Convention, therefore, has direct application to outer space.

The Convention does not establish a ban on all environmental modification technologies for military or hostile purposes, but only for those which have widespread, long-lasting or severe effects. No definition of these terms may be found in the Convention itself. However, the understandings which accompany the Convention and form part of its negotiating record, define "widespread" as encompassing an area of several hundred square kilometers; "long-lasting" as lasting for a period of months or approximately a season; and "severe" as involving significant disruption or harm to human life, natural and economic resources or other assets.⁴⁶ These broad and legally non-binding provisions do not alter the largely recognized consequence that whatever is not prohibited verbis expressis by the Convention is implicitly permitted.⁴⁷ Thus, non-hostile techniques are not prohibited, regardless of their effects, nor are techniques which produce destructive effects below a certain threshold.⁴⁸

Another characteristic of the Convention derives from the dual-purpose character of environmental modification technologies. The Convention states that its provisions "shall not hinder the use of environmental modification techniques for peaceful purposes" (Article

III). As a result of their dual-purpose character, the distinction between peaceful and military applications becomes very difficult to draw. Peaceful applications might include changing rainfall patterns, dissipating fog, and the diversion of hurricanes and earthquakes to name but a few.⁴⁹ Hostile applications might include triggering of earthquakes, upsetting the ecological balance of a region and destroying crops. The purpose of using environmental modification techniques in war also includes interfering with communications. Because of the difficulty of distinguishing research and development for peaceful applications from that for hostile uses, nowhere does the Convention prohibit research and development of environmental modification technologies for war-like purposes.

Article III (2) states that parties to the Convention undertake to facilitate, and have the right to participate in, the fullest possible exchange of scientific and technological information on the use of environmental modification techniques for peaceful purposes. Article IV provides that each party to the Convention undertakes "to take any measure it considers necessary in accordance with its constitutional process to prohibit and prevent any activity in violation of the provisions of the Convention anywhere under its jurisdiction or control". Such a provision would seem to have little practical significance since no definition is given as to what constitutes an "activity in violation". Furthermore, recourse to different national laws precludes the establishment of a uniform and objective set of sanctions in case of non-compliance.

No means of verification are provided for in the Convention. However, a recent study⁵⁰ has indicated that military and civilian weather satellites could assist in verifying compliance with the provisions of the Convention, though it would be difficult to determine the cause of any unusual developing weather pattern which may have been detected.

Where a state questions compliance with provisions of the treaty, it may request consultation with another state in accordance with Article V. Consultation may also take place through suitable international procedures within the framework of the UN including the services of appropriate international organizations. Furthermore, a Consultative Committee of Experts may be convened to deal with compliance matters. It would be

composed of representatives of any state party wishing to participate. The Committee is charged with transmitting to the Depositary, a report of its findings which would then be distributed to all state parties. Finally, any party having reason to believe that another party is in breach of its treaty obligations, may lodge a complaint with the UN Security Council. The Council is empowered to initiate its own investigation and parties to the Convention are obligated to cooperate with the Security Council.

(xvii) Moon Treaty (1979)

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies⁵¹ is the most recent agreement dealing directly with outer space. A Resolution was adopted by consensus in the UN General Assembly on 5 December 1979 recommending the Treaty for signature and the Treaty came into force on 11 July 1984.⁵² It should be noted that as of 31 March 1984 there are only four parties to this Treaty. The result of lengthy discussion and compromise, the Moon Treaty is a composite of general principles and specific provisions outlining permissible activity on the moon and other celestial bodies.⁵³ The Treaty is a further elaboration of certain concepts in the Outer Space Treaty. While it does not apply to the earth or earth orbits and while few states are party to the Treaty, the principles it contains regarding space conduct are of great interest.

The Moon Treaty is modeled on the Outer Space Treaty; space activities are to be carried out in accordance with international law in the interest of maintaining peace and security and promoting international cooperation and understanding. Exploration and use is to be carried out for the benefit and in the interests of all nations. All of these principles, while general, are of relevance to space law today.

There are several key articles in the Moon Treaty which serve to establish state conduct for the moon and other celestial bodies. Article IV (1) provides that exploration and use of the moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries regardless of their degree of economic or scientific development. In carrying out activities, states shall be guided by the principle of cooperation and mutual assistance.⁵⁴ Secondly, scientific investigation must be carried out without discrimination and on the basis of equality and in accordance with international law.

While arms control was not a major focus of discussion during the negotiations, some nations did express concern over the military implications of certain space activities. Article III of the Moon Treaty contains the only provision specifically addressed to military activities. Paragraph 1 provides that the moon and other celestial bodies shall be used "exclusively for peaceful purposes". While in this case the language is virtually identical to that found in Article IV (2) of the Outer Space Treaty, the effect is to expand the area of application of the peaceful purposes admonition.⁵⁵ Under the Outer Space Treaty only the moon and celestial bodies were specifically limited to peaceful purposes. Because of the definitional concept contained in Article I of the the Moon Treaty, orbits around and other trajectories to and around the moon and other celestial bodies must also be devoted to peaceful purposes.⁵⁶ With regard to Article III (2), some nations wanted to assure that this provision did not differ in effect from Article 2 (4) of the UN Charter and did not derogate from the right of self-defence under Article 51 of the UN Charter. Article III (2) of the Moon Treaty prohibits "any threat or use of force or any other hostile act or threat of hostile act" on the moon. Since there is no definition of the term "hostile act", there is no firm understanding as to how a hostile act might differ from the use of force. In this regard, it should be noted that when France signed the Moon Treaty it reported a clarification to the United Nations as follows:

France is of the view that the provisions of Article 3, Paragraph 2 of the agreement relating to the use or threat of force cannot be construed as anything other than a reaffirmation, for the purposes of the field of endeavour covered by the agreement, of the principle of the prohibition of the threat or use of force, which states are obliged to observe in their international relations, as set forth in the UN Charter.⁵⁷

Article III (2) also prohibits the use of the moon as a base for threatening the earth or spacecraft.

Paragraph 3 of Article III prohibits orbiting of nuclear and other kinds of mass destruction weapons around the moon and any other trajectory to or around the moon. It also forbids the placement or use of such weapons on the moon. It would seem that paragraph 3 attempts to settle the question caused by the omission of the moon from the prohibition contained in Article IV (1) of the Outer Space Treaty regarding placement of nuclear weapons and other weapons of mass destruction.

Paragraph 4 forbids "the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres" on the moon.

As regards verification, parties to the agreement are allowed to inspect all space vehicles, equipment, facilities stations and installations belonging to any other party. Pursuant to Article XV (1), the Agreement authorizes every contracting state to conduct such inspection "on its own behalf or with the full or partial assistance of any other state party or through appropriate international procedures within the framework of the United Nations and in accordance with the Charter".

If a party believes another party is not fulfilling the obligations incumbent upon it pursuant to the Moon Treaty, it may request consultations with a view to arriving at a mutually acceptable resolution of any controversy (Article XV (2)). Should no settlement be forthcoming, the parties may take measures to solve their dispute by any other peaceful means. The assistance of the Secretary-General may be sought by either party in order to resolve the controversy (Article XV (3)).

(xviii) International Telecommunication Convention (1982)

The presently applicable International Telecommunication Convention was adopted in 1982 in Nairobi.⁵⁸ The purposes of the International Telecommunications Union (ITU) are to maintain and extend international cooperation for the improvement and rational use of telecommunications, to ensure the efficient use of the radio spectrum and to harmonize the actions of states in the attainment of these ends.⁵⁹ The ITU is also responsible for the allocation of radio frequencies for all outer space activities and for ensuring that the radio spectrum is utilized without harmful interference. With respect to the use of the geostationary orbit, provision is made requesting states to undertake efficient and economical utilization to ensure equitable access for all members (Article 33).

However, the opportunities for an equitable and rational allocation of orbital positions are reduced by Article 38 (1) of the Convention which states:

Members retain their entire freedom with regard to military radio installations of their army, naval and air forces.

III. United Nations General Assembly Resolutions

The evolution of space law has closely followed space exploration. It should be noted that even prior to the first launchings, it was thought that on the basis of international law, outer space was res communis.⁶⁰ Thus, as was the case with the high seas, space was understood to be free for all to use and to be beyond sovereign claims. Even while the use of outer space was at an experimental stage, the need for its regulation was strongly defended. Initial efforts of the United States in early 1957⁶¹ to ban the use of cosmic space for military purposes did not meet with a favourable response from the Soviet Union.⁶² However, the twelfth session of the United Nations General Assembly adopted Resolution 1148 calling for the "joint study of an inspection system designed to ensure that the sending of objects through outer space should be exclusively for peaceful and scientific purposes."⁶³

Soon after the launching of the first Soviet and American satellites⁶⁴ the international legal aspects of outer space activities began to be examined. In 1958, the United Nations General Assembly created an ad hoc Committee on Peaceful Uses of Outer Space by Resolution 1348 entitled "Question of the Peaceful Use of Outer Space."⁶⁵ Already at this early stage the Assembly resolved to "promote energetically the fullest exploration and exploitation of outer space for the benefit of mankind".⁶⁶ This was to be achieved on the basis of sovereign equality by international cooperation in the study and utilization of space for peaceful purposes. It was thought that the implementation of these aims could best be carried out by the establishment of an appropriate international body within the framework of the United Nations. Consequently, the ad hoc Committee was formed composed of eighteen members and charged with reporting to the General Assembly at its next session, on:

- (1) the activities and resources of the U.N. and other international bodies relating to the peaceful uses of outer space;
- (2) the area of international cooperation and programs in the peaceful uses of outer space which could appropriately be undertaken within the U.N.;
- (3) the future organizational arrangements to facilitate international cooperation in space activities; and

- (4) the nature of legal problems which might arise in carrying out space programs.

The ad hoc Committee obtained permanent status, as a Standing Committee, ⁶⁷ in 1959 by UNGA Resolution 1472 almost one full year later.⁶⁸ This resolution recognized the common interest of mankind as a whole in furthering the peaceful use of outer space and, significantly, made mention of the paramount aim to benefit all states "irrespective of their economic or scientific development" through space exploration. The Assembly also noted that the U.N. should promote international cooperation in outer space. The next significant Resolution, 1721, adopted unanimously in December 1961,⁶⁹ would serve to guide the subsequent evolution of space law. In addition to reiterating the afore-mentioned principles, the Assembly adopted the guiding principle that outer space and celestial bodies would be "free for exploration and use by all States in conformity with international law and would not be subject to national appropriation".⁷⁰ The Assembly called upon states launching objects to furnish COPUOS with information regarding launch details and acquired scientific and technological knowledge. This information was to be communicated through the Secretary-General who was requested to maintain a public registry of all furnished details. COPUOS was instructed to maintain close links with the Secretariat in order to ensure full cooperation and interaction between government and non-governmental organizations concerned with outer space matters.

Thus by 1961 three important themes had emerged:

- (1) that exploration was to be according to international law;
- (2) that all states would be free to explore and use the outer space environment;
- (3) that space could not be subject to claims of sovereignty.

These themes were further elaborated upon in 1963 by the very important Resolution 1962 entitled "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space".⁷¹ The following guiding principles were propounded:

- (1) the exploration and use of outer space should be carried on for the benefit and in the interest of all mankind;
- (2) outer space and celestial bodies should be free for exploration and use by all states on a basis of equality and in accordance with international law;
- (3) outer space and celestial bodies should not be subject to national appropriation;
- (4) the activities of states in the exploration and use of outer space should be carried on in accordance with international law, including the Charter of the United Nations;
- (5) states should bear international responsibility for national activities in outer space, this responsibility to be borne by the states alone or by the international organizations and by the states participating in them; it was also set forth that national activities should require continuing supervision by the state concerned;
- (6) in the exploration and use of outer space, states should be guided by certain principles of responsibility, as well as request consultation between interested parties;
- (7) the state on whose registry an object launched in outer space is carried should retain jurisdiction and control over such object and its component parts;
- (8) each state which launches or procures a launching of the object into outer space should be internationally liable for damage to a foreign state by such object or its component parts on the earth, in air space or in outer space;
- (9) states should regard astronauts as envoys of mankind in outer space and should render to them all possible assistance; the principle of the return of astronauts and their space vehicles to the state of registry was also laid down.⁷²

The Declaration of Legal Principles, as well as its precursor Resolution 1721, did not contain any specific controls on military uses of outer space and/or celestial bodies, but did make reference to the general principle that the exploration and use of outer space should be carried on for peaceful purposes.

Another factor which favoured progress in the enhancement of public order in space during this period could be broadly classified as community concerns. In 1962, within the Eighteen-Nation Committee on Disarmament (ENDC) several countries pressed for priority in the question of the Peaceful Uses of Outer Space.⁷³ During 1963, a joint draft resolution to ban nuclear and other weapons of mass destruction from outer space was initiated in the ENDC. Following private negotiation and agreement between the United States and the Soviet Union, the draft was referred to the General Assembly. On 13 October 1963, the General Assembly approved the draft as Resolution 1884 (XVIII). In its operative part, the resolution calls upon all states: "(a) to refrain from placing in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, installing such weapons on celestial bodies, or stationing such weapons in outer space" or in any way participating in the conduct of the foregoing activities. The substance of this resolution eventually was incorporated into The Outer Space Treaty of 1967 as Article IV (1).

These important concepts formed the basis for conduct in outer space and future space law conventions. It is worthy of note that Resolution 1962 was adopted unanimously. Nevertheless, the adoption of the significant provisions in all the afore-mentioned General Assembly resolutions, while welcomed, were considered only as provisional steps in establishing outer space law.⁷⁴ From a legal point of view, General Assembly resolutions do not constitute binding international law, and have the character of recommendations only. However, in some cases certain resolutions, may reflect customary international law or represent a step in the process of the progressive development of the law.

It is noteworthy that as regards Resolution 1962 many states declared, before its adoption, that their governments would consider the resolution as legally binding, or would at least agree to comply with its principles.⁷⁵

However one characterizes the legal impact of General Assembly resolutions, it is evident that subsequent space treaty law has reflected many principles embodied in these early resolutions. More recent resolutions in the General Assembly have had less impact on the development of the law of outer space. They have, however, since 1981, highlighted an apprehension felt by some nations over an apparent trend towards stationing weapons in outer space.

IV. Summary

On the basis of the foregoing review of international law relating to arms control and outer space, certain themes, emerge. These may be summarized as follows:

- (1) General international legal norms regarding military activities on earth (e.g. the UN Charter) also apply to military activities in outer space (Outer Space Treaty and Moon Treaty).
- (2) Outer space and celestial bodies are not subject to national appropriation and are free for non-prohibited uses such as exploration and scientific investigation by all states (Outer Space Treaty and Moon Treaty).
- (3) States bear international responsibility for their national activities in outer space and on celestial bodies (Outer Space Treaty, Moon Treaty and Liability Convention).
- (4) Certain military activities in outer space are consistent with international law. These include:
 - (a) The use of military personnel in space (Outer Space Treaty).
 - (b) The use of space-based remote sensors for military purposes (ABM Treaty, SALT Treaties, Threshold Test Ban Treaty, and Peaceful Nuclear Explosions Treaty).

- (c) The use of space-based communications, navigation, meteorological systems.
- (5) Certain military activities in space are inconsistent with international law. These include:
- (a) Interference with space-based remote sensors used for military purposes as between the USA and USSR (ABM Treaty, SALT Treaties, Threshold Test Ban Treaty and Peaceful Nuclear Explosion Treaty).
 - (b) Placement of nuclear weapons and other weapons of mass destruction in orbit around the earth and on celestial bodies or in orbit around them. (Outer Space Treaty, Moon Treaty, SALT II). This includes new fractional orbital systems (SALT II).
 - (c) Hostile acts or use of force on celestial bodies and orbits around them. (Moon Treaty).
 - (d) Placement of military bases and conduct of military tests or manoeuvres on celestial bodies and in orbits around them. (Outer Space Treaty and Moon Treaty).
 - (e) Testing of nuclear weapons in outer space (Partial Test Ban Treaty).
 - (f) Development, testing, deployment of space-based ABM systems or components (ABM Treaty).
 - (g) Military or hostile use of environmental modification techniques in outer space (Environmental Modification Treaty).

V. Conclusion

Opinions may vary on whether or not each of the five categories outlined above could be extended to encompass other space activities beyond those itemized. Opinions will also differ on the legal status of many of the themes listed. Much of the discussion surrounding what activities are permitted and what are proscribed focusses on certain key definitions such as "peaceful purposes", "free use", "militarization". Consideration of these definitions may facilitate the future deliberation of the CD on arms control and outer space.

NOTES

- (1) (1946) no. 67 United Kingdom Treaty Series, Cmd. 7015. Signed 26 June 1945; entered into force 24 October 1945.
- (2) (1980) no. 58 United Kingdom Treaty Series, Cmd. 7964. Opened for signature 23 May 1969; entered into force 27 January 1980.
- (3) Supra, note 1.
- (4) (1961), 402 United Nations Treaty Series 71. Opened for signature 1 December 1959; entered into force 13 June 1961.
- (5) The International Geophysical Year (IGY) was organized under the auspices of the International Council of Scientific Unions in 1957-58 and was planned and carried out by more than 50 states. Each participating state planned and developed its own programs, which were coordinated by a special Committee for the International Geophysical Year. See: Buedeler, The International Geophysical Year, UNESCO, (1957); Chapman, IGY-Year of Discovery, (1959).
- (6) See also Article IX (1) (a): "use of Antarctica for peaceful purposes only" and the first and fourth preambular paragraphs.
- (7) Stein, "Legal Restraints in Modern Arms Control Agreements", (1972), 66 American Journal of International Law, 255, 259; Vlastic, "Disarmament Decade, Outer Space and International Law", (1981), 26 McGill Law Journal 173.
- (8) Hanessian, "The Antarctic Treaty", (1959), International and Comparative Law Quarterly 436, 468.
- (9) Article II states: "Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical year, shall continue, subject to the provisions of the present Treaty".
- (10) Article III states:
"1. In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article II of the present Treaty, the contracting Parties agree that, to the greatest extent feasible and

practicable: (a) information regarding plans for scientific programmes in Antarctica shall be exchanged to permit maximum economy and efficiency of operations; (b) scientific personnel shall be exchanged in Antarctica between expeditions and stations; (c) scientific observations and results from Antarctica shall be exchanged and made freely available.

2. In implementing this Article, every encouragement shall be given to the establishment of cooperative working relations with those Specialized Agencies of the United Nations and other international organizations having a scientific or technical interest in Antarctica."

- (11) According to Article V (2), if all the contracting parties were to adhere to any broader international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, those agreements would apply to Antarctica.
- (12) Article VII (2). This provision was the first time that the two superpowers agreed on an on-site inspection system to ensure against unauthorized military activity.
- (13) Antarctica: 10th Meeting of Treaty Consultative Parties, (November 1979), Department of State Bulletin 21.
- (14) (1963), 480 United Nations Treaty Series 43. Opened for signature 5 August 1963; entered into force 10 October 1963.
- (15) Adopted in UNGA Resolution 2222 (XXI), 19 Dec. 1966. (1967) 610 United Nations Treaty Series 206. Opened for signature 27 January 1967; entered into force 10 October 1967.
- (16) Vlastic, supra, note 7, 170.
- (17) Goedhuis, "What Additional Arms Control Measures Related to Outer Space Could be Proposed?", in: Jasani (ed.), Outer Space - A New Dimension of the Arms Race, (1982), 297, 299.
- (18) UNGA Resolution 1884, 13 October 1963.

- (19) Christol, "Article Four and 1967 Principles Treaty: Its Meaning and Prospects for its Clarification", Paper submitted at the XXIXth Congress of the International Institute of Space Law of the IAF, held in Dubrovnik, 1-8 October 1978, 6.
- (20) Stein, supra, note 7, 260.
- (21) Marcoff, Traité de droit international public de l'espace, (1973), 357.
- (22) Christol, supra, note 19, 26.
- (23) Ibid.
- (24) UN Doc. S/RES/255 (1968). (1967) 634 United Nations Treaty Series 326. Opened for signature 14 February 1967; entered into force 22 April 1968.
- (25) (1969) 672 United Nations Treaty Series 119. Opened for signature 22 April 1968; entered into force 3/December 1968.
- (26) Articles II, III and IV.
- (27) (1970) 729 United Nations Treaty Series 161. Opened for signature 1 July 1968; entered into force 5 March 1970.
- (28) (1973) no. 13 United Kingdom Treaty Series, Cmd. 5266. Opened for signature 11 February 1971; entered into force on 18 May 1972.
- (29) Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War. (1972), 807 United Nations Treaty Series 57. Signed 30 Sept. 1971; entered into force 30 Sept. 1971.
- (30) Agreement on Measures to Improve the Direct Communications Link. (1972), 806 United Nations Treaty Series 402.
- (31) Agreement on the Prevention of Nuclear War. (1973), 24 United States Treaties 1478. Signed 22 June 1973; entered into force 22 June 1973.

- (32) (1974) no. 16 United Kingdom Treaty Series, Cmd 5551. Opened for signature 29 March 1972; entered into force on 1 September 1972.
- (33) Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. (1976) no. 11 United Kingdom Treaty Series, Cmd 6397. Opened for signature 10 April 1972; entered into force 26 March 1975.
- (34) Treaty between the USA and the USSR on the Limitation of Anti-ballistic Missile Systems. Treaties and Other International Acts, Series 7503, (Washington: US Department of State, 1973). Signed 26 May 1972; entered into force 3 October 1972. Protocol to the Treaty between the USA and the USSR on the Limitation of Anti-ballistic Missile Systems. UN Doc. A/9698, Annex III, 9 August 1974. Signed 3 July 1974; entered into force 24 May 1976.
- (35) Interim Agreement Between the USA and the USSR on Certain Measures with Respect to the Limitation of Strategic Offensive Arms. Treaties and Other International Acts, Series 7504 (Washington: US Department of State, 1972). Signed 26 May 1972; entered into force 3 October 1972.
- (36) Treaty Between the USA and the USSR on the Limitation of Strategic Offensive Arms, and Protocol. CD/28, 27 June 1979 and CD/29, 2 July 1979. Signed 18 June 1979.
- (37) Treaty Between the USA and the USSR on the Limitation of Underground Nuclear Weapon Tests. U.N. Doc A/9698, Annex I and II, 9 August 1974. Signed 3 July 1974.
- (38) Treaty Between the USA and the USSR on Underground Nuclear Explosions for Peaceful Purposes. CCD/496, 23 June 1976 and CCD/496/Corr. 1, 5 August 1976. Signed 28 May 1976.
- (39) Adopted in UNGA Res. 3235 (XXII), 12 Nov. 1974. (1978) no. 70 United Kingdom Treaty Series, Cmd 7271. Opened for signature 14 Jan. 1975; entered into force 15 September 1976.
- (40) UNGA Resolution 1721 (XVI), 20 Dec. 1961.

- (41) In Articles V and VIII.
- (42) Matte, Aerospace Law: From Scientific Exploration to Commercial Utilization, (1977), 159 and authorities therein cited.
- (43) Vlastic, supra, note 7, 190.
- (44) Goedhuis, supra, note 17, 298.
- (45) (1979) no. 24 United Kingdom Treaty Series, Cmd. 7469. Opened for signature 18 May 1977; entered into force 5 October 1978.
- (46) Understanding to Article I reproduced in Agreement Governing the Activities of States on the Moon and other Celestial Bodies, Committee on Commerce, Science, and Transportation, 95th Cong., 2nd Session, May 1980, 250.
- (47) Dolman, Resources, Regimes, World Order, (1981), 322.
- (48) Krieger, Disarmament and Development. The Challenge of the International Control and Management of Dual-Purpose Technologies, (1981), 41.
- (49) In 1975, Canada submitted a working paper to the Conference of the Committee on Disarmament which groups 19 technologies within three main categories: atmospheric modification; modification of the oceans; and modification of the land masses and water systems associated with them. CCD/463, 5 August 1975; see also CCD/465, 8 August 1975 for the Swedish delegation's study.
- (50) Jasani, Outer Space: A New Dimension of the Arms Race, (SIPRI), (1982), 111.
- (51) UN Doc. A/RES/34, 68, 14 Dec. 1979.
- (52) For an analysis of the development of the Treaty, see Matte, "Treaty Relating to the Moon", in: Jasentuliyana and Lee (eds.), Manual on Space Law, vol. I (1979), 253; Reijnen, "The History of the Draft Treaty on the Moon" (1975), 19th Colloq. on the Law of Outer Space 357.

- (53) Reference to the moon hereinafter shall include other celestial bodies as well. Article 1(1) states that provisions of the agreement relating to the moon shall also apply to the other celestial bodies within the solar system, other than the earth, except in so far as specific legal norms enter into force with respect to any of these celestial bodies.
- (54) Article IV (2). It is stressed that international cooperation in pursuance of the agreement " should be as wide as possible".
- (55) Norris and Bridge, "Some Implications of the Moon Treaty with Regard to Public Order in Space", (1979) 23rd Colloquium on the Law of Outer Space 57, 57.
- (56) Article I (2) states that reference in the Agreement to the Moon shall include orbits around or other trajectories to or around it.
- (57) Supra, note 56.
- (58) Final Acts of the Plenipotentiary Conference, International Telecommunications Union, Nairobi, 1982. Opened for signature 6 November 1982; entered into force, 1 January 1984. This Convention replaces the 1973 Malaya-Torremolinos Convention, (1975) United Kingdom Treaty Series, Cmd 6219.
- (59) See generally Article IV of the Convention.
- (60) Brownlie, Principles of Public International Law, (3rd ed.), (1979), 266-7.
- (61) In its Memorandum submitted to the First Committee of the United Nations General Assembly on 12 January 1957, the United States proposed that "the first step toward the objective of assuring that future developments in outer space would be devoted exclusively to the peaceful and scientific purposes would be to bring the testing of such objects under international inspection and participation". UN Document A/C.1/783.
- (62) For the position of the Soviet Union see UN Document DC/SC.1.49 (18 March 1957) and DC/SC/1/55 (30 April 1957).
- (63) UNGA Res. 1148 (XII), 14 November 1957.

- (64) The first Sputnik was launched on 4 October 1957, followed closely by Explorer 1 on 31 January 1958.
- (65) UNGA Res. 1348 (XIII), 15 December 1958.
- (66) Ibid.
- (67) The Committee on the Peaceful Uses of Outer Space or COPUOS as it is commonly termed.
- (68) UNGA Res. 1472 (XIV), 12 Dec. 1959.
- (69) UNGA Res. 1721 (XVI), 20 Dec. 1961, "International Cooperation in the Peaceful Uses of Outer Space".
- (70) Ibid.
- (71) UNGA Res. 1962 (XVIII), 13 Dec. 1963.
- (72) Matte, Aerospace Law, (1969), 106-7.
- (73) United Nations Department of Political and Security Affairs, The United Nations and Disarmament, 1945-1970, 19.
- (74) Kopal, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies", (1966), McGill Yearbook of Air and Space Law 463, 467.
- (75) Kopal, supra, note 74, 467.

ANNEX 1

STATUS OF MULTILATERAL AGREEMENTS RELATING TO OUTER SPACE

	<u>Opened for Signature</u>		<u>No. of Parties as of (date)</u>
1. Charter of the United Nations	1945	158	31 March 1984
2. Antarctic Treaty	1959	32	31 December 1984
3. Partial Test Ban Treaty	1963	111	31 December 1984
4. Outer Space Treaty	1967	92	31 December 1984
5. Treaty of Talatelolco	1967	29	31 December 1984
6. Rescue & Return Agreement	1968	79	31 March 1984
7. Non-Proliferation Treaty	1968	127	31 December 1984
8. Seabed Treaty	1971	81	31 December 1984
9. Convention on International Liability for Damage Caused by Space Objects	1972	72	31 March 1984
10. Biological Weapons Convention	1972	104	31 December 1984
11. Registration Convention	1975	32	31 December 1984
12. Environmental Modification Convention	1977	54	31 December 1984
13. Moon Treaty	1979	4	31 March 1984
14. International Telecommunications Convention	(a) 1973	156	31 March 1984
	(b) 1982	8	30 June 1985

Sources:

Bowman, M.J. and D.J. Harris. Multilateral Treaties: Index and Current Status. London: 1984.

United States. Arms Control and Disarmament Agency. 1984 Annual Report. Washington: April, 1985.

JAPAN

Application of (Nuclear) Safeguards Remote Verification Technology
to verification of a chemical weapons conventionIntroduction

Success in the chemical weapons convention negotiations is to a major degree dependent on the resolution of the problems concerning verification, and many proposals to this end have been made by the member States of the Conference on Disarmament.

Among these various proposals, one of the most promising as a verification technology for chemical weapons facilities is RECOVER (Remote Continual Verification) technology (CD/271), which technology was originally developed for the Arms Control and Disarmament Agency of the United States Government as a global data collection system for the safeguard of nuclear material. A "second generation" system now being developed in Japan will permit a safe, economic and reliable transmittal of digital data to a central monitoring organization from various sensors placed at facilities, and would thus appear suitable for application to verifying the inactive status of chemical weapons facilities and the situation of chemical weapons stockpiles, elimination processes etc.

An outline of the Safeguards Remote Verification Technology now being developed in Japan is given below, together with an examination of its possible application to a chemical weapons verification system.

1. Safeguards Remote Verification TechnologyDevelopment status

RECOVER technology was first developed in 1981 by the United States as a prototype system utilizing the telephone network, while further research was taken up by Japan. At present, an advanced system utilizing the domestic telephone network and another system utilizing satellite communications are being developed, which development is to be completed in 1985.

The first generation technology had various limitations, such as the low reliability of the hardware and the ability only to transmit "on-off" data from the sensors, etc. In contrast, the advanced type now being developed has increased the reliability of the hardware so that it will be maintenance-free for a period of about one year, and will also be able to transmit still images and alpha-numerical data, as well as being able to respond to remote commands from a monitoring centre to play back information recorded by closed-circuit television cameras at facilities and transmit the necessary information to said organization.

The technology has thus become more practical as a verification system. Furthermore, with the addition of satellite telecommunication hardware costing about ¥13,000,000 (approximately \$52,000), it would be possible to link up the

(inter)national monitoring organization with facilities located in remote areas where telephone network access would be difficult. A system concept illustration of Safeguards Remote Verification as is being developed in Japan is shown in Figure 1. (Figure 2 shows the technology as applied on board a ship).

System characteristics

The system characteristics of this technology as an automatic remote monitoring system is as follows:

(a) Communication means ... ordinary public telephone lines, including satellite circuits, may be used for data traffic of up to approximately 2,400 bits per second, as is the normal case (special lines may be used for traffic of greater data intensity).

(b) Automated operation ... the system is designed to be tamper-resistant and, with the use of high-reliability hardware, should require maintenance only about once a year; thus reducing the frequency of mandatory visits by inspectors.

(c) Protection of transmitted information ... information to be transmitted is scrambled by a combination of a random factor and a code key, and the accuracy of the transmitted information is assured by various parity checks.

(d) Transmittable information ... "on-off" data, analogous information, still images and alpha-numerical data.

(e) Application ... transmission of information to a monitoring centre of a facility where inspectors are permanently stationed or to a (inter)national monitoring organization.

A brief description of the hardware being developed as Safeguards Remote Verification Technology is given in Table 1.

2. Application of Safeguards Remote Verification Technology to a chemical weapons verification system

In examining possible application of Safeguards Remote Verification Technology to a chemical weapons verification system, it is necessary first to clarify in detail what is the exact demand on verification, whether it would suffice to detect abnormalities at the facility monitored or whether more substantial information is required, as well as the overall system of on-site inspection within which framework this technology would be applied.

However, for the purposes of this section, such real-life considerations will be put to one side and possible application of this technology will be shown in an exemplar manner. The demand on verification is understood to be as follows:

(a) as regards chemical weapons stockpile facilities and former production facilities to be destroyed at a future date, verification of their inactive status;

as to elimination facilities and permitted production facilities, monitoring of their activities;

as to the transshipment of chemical weapons, the monitoring of possible container abnormalities both prior to and after completion of transshipment.

(b) communications between the facilities and monitoring organization will be conducted by means of an existing communications network.

Possible applications

Given the understanding above, exemplar application of Safeguards Remote Verification Technology to various facilities for chemical weapons stockpiling, producing, eliminating etc. would be as shown in Table 2.

The estimation of cost was made on the basis of the cost of a complete verification system comprising of:

- for facilities, whose size was understood to be on a scale similar to that of the facilities discussed at the chemical weapons verification workshop at the Tooele Army Depot in November 1983, sensors, on-site multi-plexers, network control units and satellite communication systems;
- for transshipment containers, a complete set of optical fibre seals.

In this estimation the cost of verification hardware for the various facilities were as follows:

- stockpile facilities Y38,000,000 (approximately \$152,000)
- permitted production facilities Y75,000,000 (\$300,000)
- former production facilities Y46,000,000 (\$184,000)
- elimination facilities Y75,000,000 (\$300,000)

(It need not be stressed that these figures are in any case just illustrative and the real cost will vary according to the scale of the facility, its configuration etc.).

Conclusions

The RECOVER system, which was developed for safeguarding nuclear material has, in the course of development of such "second generation" technology as the addition of remote control capability, improved reliability and the utilization of satellite communication, become a more practical system of Safeguards-related technology and the economic aspect, such as the cost of various hardware, is improving rapidly. It is recommended that the Conference on Disarmament give due consideration to a possible application of this and related technology to the verification of a chemical weapons convention, thus greatly advancing its work in the field of verification technology for a comprehensive ban on chemical weapons.

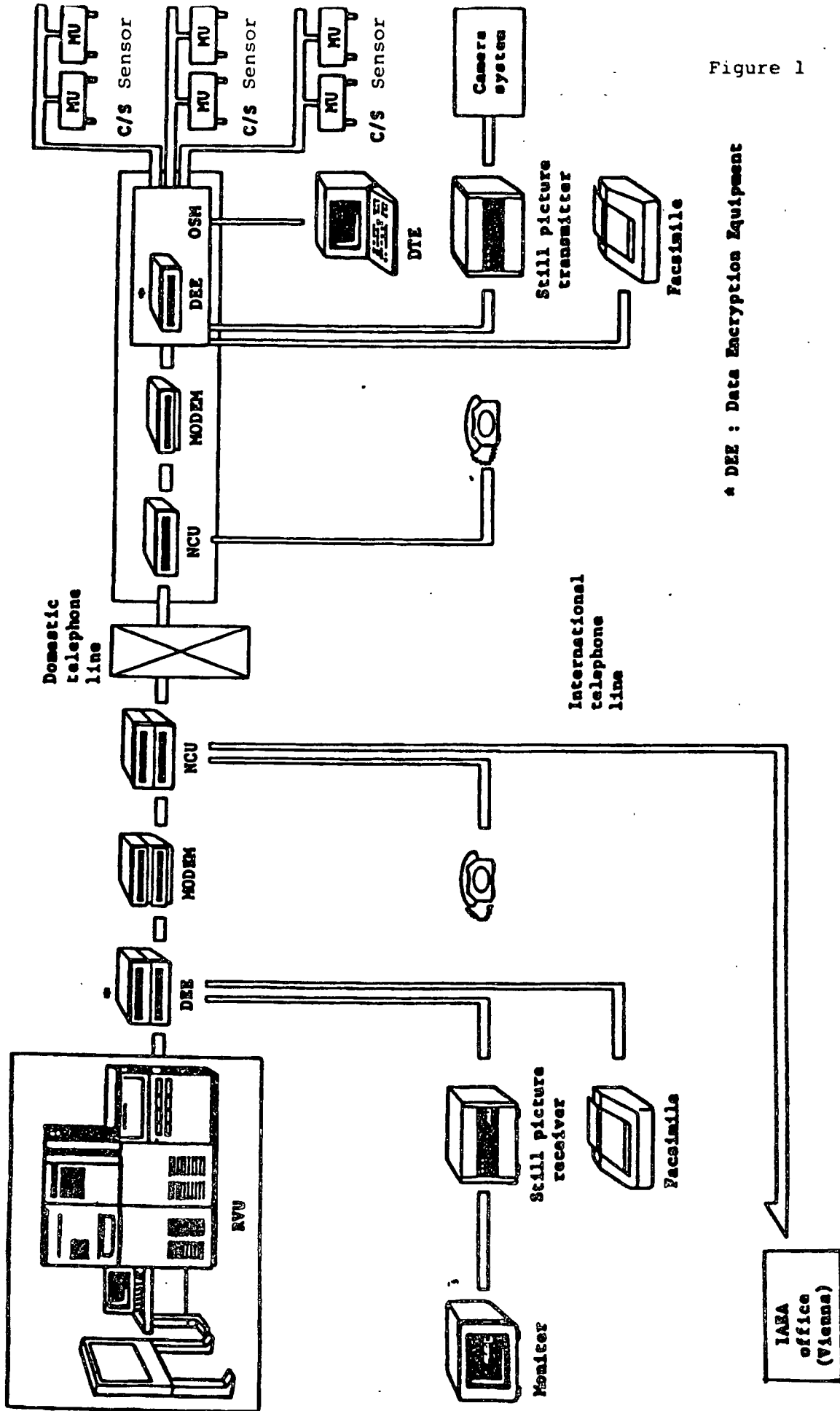
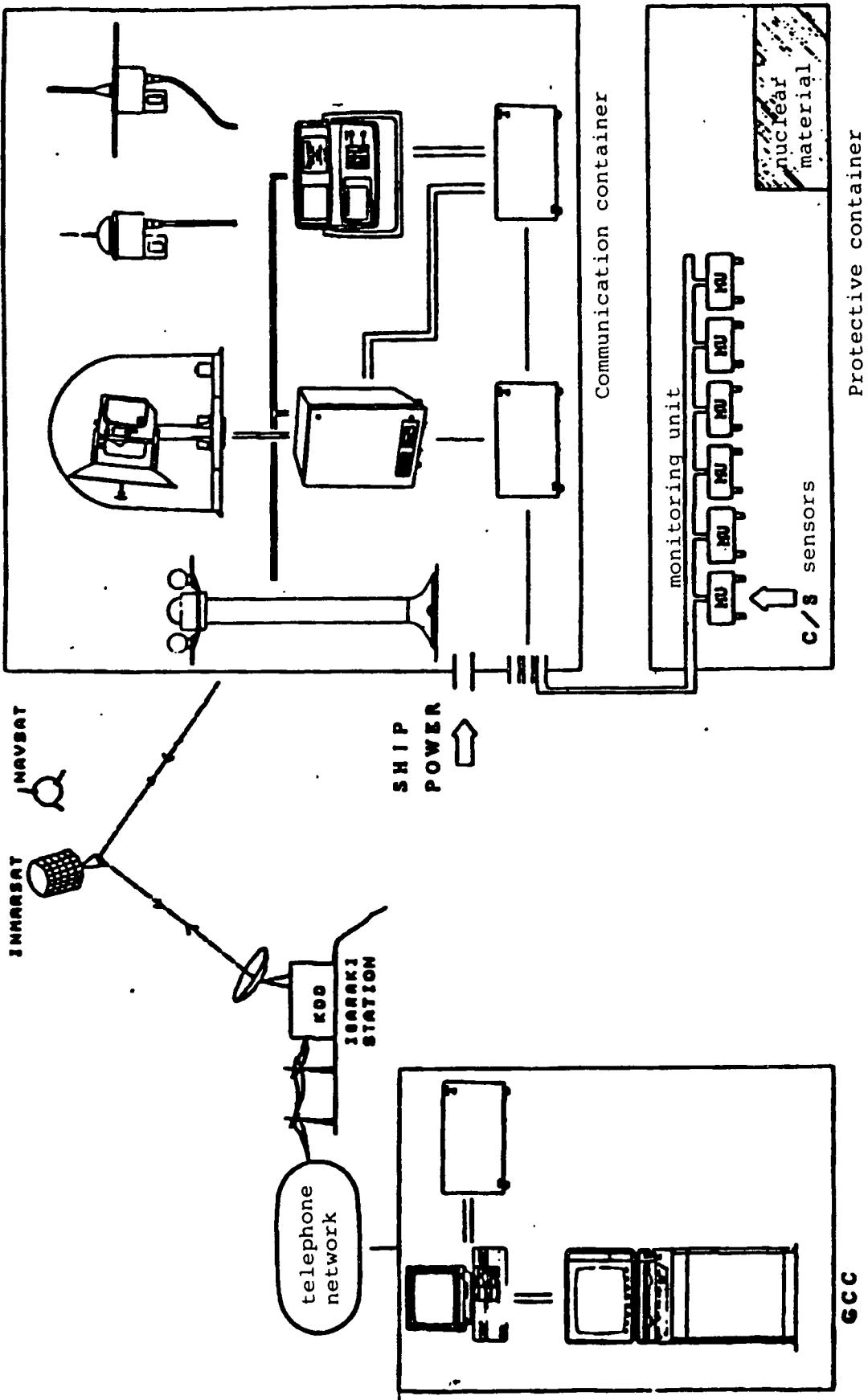


Figure 1

Conceptual design of the Safeguards Remote Verification System

Figure 2



Remote Monitoring System
of Nuclear Material under Transportation

Table 1











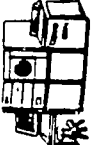
Examples of hardware being developed in Japan as Safeguards Remote Verification Technology				
Function	Hardware	Shape	Description	Approximate cost (in yen)
Sensors	monitor camera (Optical surveillance system)		Small inexpensive video recording system with motion monitor for detecting tampering	400,000
	Intrusion sensor (Intrusion detection system)		Sensors utilizing long wave-length infrared or micro wave beams are highly reliable and may be so placed as to cover an entire area	100,000
Portal surveillance	Portal monitor		A combination of metal detectors, motion monitors, optical surveillance equipment and intrusion alarms	50,000,000
	Optical fiber seal		Bundle of approximately 60 optical fibers used to check on-site, whether a seal has been broken or not. Very high reliability.	1,000
Seals	Opto-electric seal		Utilizes optical fibers to check by remote control, whether a particular seal is still effective and whether there has been any tampering	100,000
	MU (Monitoring unit)		About the size of a cigarette packet, but can monitor the condition and (non-)tampering of the sensors and transmit that as 8 bit data to OSM	100,000
Data processing and transmission	OSM (On-site Multiplexer, Data transmission equipment, Data encryption equipment)		Processes data from MUs and, where there are anomalies, automatically informs the central surveillance equipment by code. Also responds to some remote control from it	2-3,000,000
	Still picture transmitter (SPT)		Connected to an OSM, transmits/receives images the monitor camera has picked up. The centre has reception equipment, the facilities have the transmitting equipment	5,000,000 (1 set)
	Still picture receiver (SPR)		Responds to commands from the OSM or RVU to open/close the communication circuit	200,000
	Satellite communication system (Transmitter/Receiver unit-Antenna unit)		Allows link-up with centre where no telephone network access exists. There are compact units	13,000,000
Central surveillance	Central surveillance equipment		Controls the OSMs at the various facilities, analyses the situation thereat, and, where anomalies are detected, indicates action to be taken	20,000,000

Table 2

Exemplar application of Safeguards Remote Verification Technology to various chemical weapons facilities		approximate cost
Object to be verified	Hardware application	
Chemical Weapons facilities	<p>Stockpile facility</p>	<p>monitor camera x 5 intrusion sensor x 12 opto-electric seal x 3 OSM x 1 NCU x 1 satellite communication system and related equipment x 1</p> <p>¥38,000,000 (\$152,000)</p>
	<p>permitted facility</p>	<p>monitor camera x 8 portal monitor x 1 OSM x 1 NCU x 1 satellite communication system and related equipment x 1</p> <p>¥75,000,000 (\$300,000)</p>
	<p>former production facility (to be eliminated)</p>	<p>monitor camera x 9 intrusion sensor x 12 opto-electric seal x 3 OSM x 1 NCU x 1 satellite communication system and related equipment x 1</p> <p>¥46,000,000 (\$184,000)</p>
Others	<p>Elimination facility</p>	<p>monitor camera x 15 intrusion sensor x 5 OSM x 1 NCU x 1 satellite communication system and related equipment x 1 process monitor (in-flow sensor, control system) x 1</p> <p>¥75,000,000 (\$300,000)</p>
	<p>containers</p>	<p>optical fiber seal</p> <p>monitoring of possible container abnormalities both prior to and after completion of trans-shipment</p> <p>¥1,000 each (\$4 each)</p>
		<p>Data processing and transmission</p>

CONFERENCE ON DISARMAMENT

CD/620
CD/CW/WP.119
23 July 1985
Original: ENGLISH

German Democratic Republic

National Verification Measures to Implement the Convention on the Prohibition of Chemical Weapons

Introduction

Effective measures to verify compliance with a future convention banning chemical weapons are of great importance. Every State Party must be given the assurance that the obligations undertaken are scrupulously observed by all the parties to the convention. This issue deserves particular attention because of the current activities to start the production of a new generation of chemical weapons - binary weapons.

The socialist countries have proposed a whole array of mechanisms of verification.

National verification measures are of fundamental significance. In applying such measures, States would live up to the responsibility they have for the implementation of the convention. What is more, those measures represent the basis on which the entire system of verification must be built.

The purpose of the Working Paper is to stimulate the drafting of provisions pertaining to two aspects of national verification, that is guidelines for the establishment of a national verification authority and for the control of certain chemicals.

Part I contains proposals and possible organizational guidelines for the operation of a national authority. The establishment of a special or the entrusting of an already existing body will enable the State Party concerned to meet the responsibility for the implementation of the convention on its territory and for compliance with it. The national authority should have appropriate powers and co-operate with the Consultative Committee, especially with regard to the exchange of data and support for international procedures. It may be set up as a single body. Its duties may also be performed by several separate bodies.

Part II sets out possible guidelines for a national system of accounting for and control of chemicals in connection with the convention. An important aspect of the activities of the national authority is to ensure that chemical weapons are not produced.

The problem of non-production recently acquired added topicality in view of the plans to produce a new generation of chemical weapons. The Convention must, therefore, provide for appropriate measures to guarantee that such weapons are not manufactured in a way circumventing the Convention. Clearly phrased regulations concerning permitted activities in the Convention will have to satisfy that requirement.

The Working Paper sets forth the ideas regarding the implementation of national verification measures that have already been dealt with by the Conference. It draws on the positions specified in documents CD/220, CD/333 and CD/334. Also, it takes into consideration what is said in document CD/482 submitted by Yugoslavia and document CD/313 presented by Canada. The Paper does not claim to be complete. The suggestions made in it are to help make progress. They would provide guidance to States in the discharge of their obligations under the convention. It stands to reason that, besides the functions outlined in this Paper, other tasks, e.g., the monitoring of the destruction of CW stockpiles, and facilities may be elaborated in more detail.

GUIDELINES FOR A NATIONAL SYSTEM FOR THE IMPLEMENTATION OF A
CW - CONVENTION

I. Structure and basic functions of the national system

1. Each State party to the Convention shall adopt in accordance with its constitutional process measures it considers necessary to implement the Convention and in particular, to prohibit and prevent, on its territory or anywhere under its jurisdiction or control, any activity which would constitute a violation of the Convention. In order to provide for an appropriate instrument to fulfil these undertakings the State party should establish a national system for the implementation of a CW-Convention.

Whereas the responsibility for establishing and maintaining of a national system rests entirely with the government of each State, this national system, to fulfil its purpose, should comprise the following:

- laws and other regulations constituting a legal structure of supervision and control;
- a national authority;
- organizational and operational elements at the facility level.

2. Laws and other regulations

In order to ensure strict compliance with the undertakings not to develop, produce, otherwise acquire, stockpile or retain or transfer chemical weapons;

to destroy or divert for permitted purposes existing stocks and to eliminate chemical weapons production facilities

each State party should

- establish directly binding norms with sanctions or penalties for non-compliance;
- establish regulations or other legal measures to organize the implementation of the undertakings under the Convention in respect to chemical weapons, facilities and chemicals touched upon by the Convention.^{*/}

3. National authority

Each State party shall have a special authority in order to ensure the correct execution of all measures under the Convention. To this end, a special body/bodies could be established or existing institutions, authorities or organizations could be empowered.

4. Functions, rights and duties of the national authority

(a) In the internal field

- to serve as a national focal point for questions related to the implementation of the Convention;
- to get the relevant information from the corresponding national organs, agencies and enterprises;
- to investigate the actual state of affairs concerning compliance with the Convention;

^{*/} The chemicals and the measures applicable to them will be defined in the Convention. They are called in this Paper "the chemicals concerned".

- to supervise closely the process of destruction or diversion for permitted purposes of stockpiles of chemical weapons and the elimination of production facilities for chemical weapons;
- to establish or assist the Government in establishing provisions on the possession, transfer or use of the chemicals concerned;
- to develop recommendations for the implementation of accounting and control procedures, as necessary, to enable the State to discharge its obligations under the Convention;
- to carry out national inspections;
- to install in facilities involved in activities with regard to chemicals concerned technical means of verification;
- to participate in the overseeing of measures concerning environmental protection in connection with activities to implement the Convention;
- to receive the financial means necessary for the fulfilment of its functions;
- to report to the Government on its activities and its findings.

(b) In the international field

- to serve as a point of communication with national authorities of other States Parties and the Consultative Committee;
- to keep the Consultative Committee informed on the structure and the functions of the national authority;
- to co-operate with the Consultative Committee and with national authorities of other States Parties in solving organizational and technical questions in connection with the implementation of the Convention, in particular the training of national inspectors in standard verification techniques and the use of relevant equipment;

- to transmit the data as agreed in the Convention to the Consultative Committee or its appropriate subsidiary organ and evaluate the information received from it;
- to provide the Consultative Committee with additional information, expertise and laboratory support if required for the implementation of the Convention;
- to facilitate and provide support for the inspections conducted by the Consultative Committee or its subsidiary organ in accordance with the Convention.

5. Facilities

The facilities on the territory or under the jurisdiction and control of each State Party involved in activities with regard to chemicals concerned should fulfil the following requirements:

- to implement relevant norms and regulations of the national system of control;
- to report to the national authority;
- to provide the conditions necessary for inspections;
- to allow the installation and unhampered functioning of technical means of verification.

II. The national system for account and control of chemicals

1. The national system should account and control the chemicals concerned in the State and secure the detection of possible losses or unauthorized use or removal of those chemicals.

It should comprise

- an information system;
- inspections.

2. In order to provide the national authority with the data necessary for the fulfilment of its functions the facilities as mentioned under I 5 should provide for the following information:

- facility design;
- operations involving the chemicals concerned on an annual basis, i.e.
 - (a) volume of production;
 - (b) volume of the chemicals acquired from other national facilities

or by import;

(c) use of the chemicals for production of other chemicals within the facility or for transfer;

(d) transfer to other facilities within this State, or by export.

3. The national authority should collect, process and evaluate the following data:

- the listing of current facilities producing or using the chemicals concerned;
- the record of data on the inventories of the chemicals concerned possessed at each facility;
- data on transfers;
- the record of inspection data and all operational information required for the evaluation of activities with regard to the chemicals concerned.

4. National inspections should be carried out with the aim to

- examine the design information given by the facility;
- examine the inventories of the chemicals concerned and all relevant facility records;
- observe the activities by the facility operators in respect to physical inventory taking and measuring;
- make independent measurements concerning the types and volumes of the production of the chemicals concerned and take samples if necessary;
- check seals and other containment surveillance equipment.

5. Inspectors

For the purpose of national inspections the national authority may designate a group of inspectors as well as laboratories to analyse samples.

The inspectors should have the right

- to visit all facilities involved in activities with regard to the chemicals concerned (It could be provided that the inspectors will be accompanied by facility operators);
- to request information on the production and use of the chemicals concerned and check all relevant facility records.

AUSTRALIA, BELGIUM, CANADA, FEDERAL REPUBLIC OF GERMANY,
ITALY, JAPAN, NETHERLANDS, NORWAY,
UNITED KINGDOM, UNITED STATES OF AMERICA

Draft Programme of Work for an Ad Hoc Committee on Item 1
of the Agenda of the Conference on Disarmament entitled
"Nuclear Test Ban"

- I. Scope
- Comprehensive ban on nuclear explosions in all environments
 - The question of nuclear explosions for peaceful purposes
- II. Verification
- The central importance of verification of a CTB
 - Factors affecting verification needs
 - Means for monitoring compliance
 1. national technical means
 2. international seismic monitoring network
 - (a) determination of capabilities for monitoring compliance
 - (b) steps for establishment and improvement
 - (c) institutional, administrative and financial arrangements for establishment, testing and operation
 - (d) relationship to an effective verification system
 3. other means; including an international atmospheric radioactivity monitoring network
 4. on-site inspection
 - Specific verification problems and their solutions, including
 1. monitoring large land masses
 2. methods of possible evasion
 3. chemical explosions
- III. Compliance
- Procedures and mechanisms for consultation and cooperation
 - Coordinating body, e.g. committee of experts
 - Consultative committee
 - Series of actions triggered by suspicion or violation, including complaints procedures

CONFERENCE ON DISARMAMENT

CD/622

25 July 1985

Original: ENGLISH

LETTER DATED 23 JULY 1985 ADDRESSED TO THE PRESIDENT OF THE CONFERENCE ON DISARMAMENT FROM THE DEPUTY HEAD OF THE HUNGARIAN DELEGATION TRANSMITTING THE TEXT OF THE STATEMENT ISSUED BY THE REPRESENTATIVES OF THE PARLIAMENTS OF THE WARSAW TREATY MEMBER STATES AT THE CONCLUSION OF THEIR MEETING HELD AT BUDAPEST, HUNGARY ON 14 MAY 1985

I have the honour to forward to you herewith the text of the statement issued by the representatives of the Parliaments of the Warsaw Treaty member States at the conclusion of their meeting held at Budapest, Hungary, on 14 May 1985.

Upon instructions from my Government, acting on behalf of the participants of that meeting, I hereby request that the said statement be circulated as an official document of the Conference on Disarmament.

Ferenc Gajda
Counsellor
Deputy Head of the Hungarian
Delegation to the CD

GE.85-63167

Statement

issued by the Representatives of the Parliaments
of the Warsaw Treaty member States

Budapest, 14 May, 1985

The Representatives of the Parliaments of the Warsaw Treaty member States held a meeting in Budapest, on 14 May, 1985, on the occasion of the thirtieth anniversary of the signing of the Warsaw Treaty.

The meeting was attended by:

the delegation of the National Assembly of the People's Republic of Bulgaria, led by Stanko Todorov,

the delegation of the Federal Assembly of the Czechoslovak Socialist Republic, led by Alois Indra,

the delegation of the Volkskammer of the German Democratic Republic, led by Gerald Gotting,

the delegation of the National Assembly of the Hungarian People's Republic, led by István Sarlós,

the delegation of the Sejm of the Polish People's Republic, led by Stanislaw Gucwa,

the delegation of the Grand National Assembly of the Socialist Republic of Romania, led by Nicolae Giosan,

the delegation of the Supreme Soviet of the Union of Soviet Socialist Republics, led by Lev Tolkunov and Avgust Voss.

The participants of the meeting emphasized that the Warsaw Treaty has reliably served the preservation of the historic achievements of socialism and the development of the many-sided co-operation of the allied countries, and has played an outstanding part in safeguarding and stabilizing peace in Europe and the world for three decades. The parliaments, the supreme organs representing the people's power of the member States, have considerably contributed to the deepening of the co-operation of the Warsaw Treaty member States, to the struggle for the reduction of international tension, and to the development of peaceful co-operation. On several occasions, they have consistently called on the parliaments and peoples of the world to promote efforts to curb the arms race, first of all nuclear armament, to reduce the dangers of confrontation, and to renew the process of détente.

In April this year the Warsaw meeting of the supreme party and state leaders of the Warsaw Treaty member States passed a unanimous decision on the extension of the Warsaw Treaty, convincingly proving the commitment of the member States to continue their common line aimed at peace and peaceful co-existence. The extension of the treaty is in accordance with the vital interests of the peoples of the fraternal countries and serves the stablization of peace and international security.

The Warsaw Treaty member States have never been in favour of the division of Europe and the world into confronting military blocs. They signed their treaty of defence six years after NATO had been established. As it was reconfirmed once

again at the Warsaw meeting, the member States take a stand for the simultaneous disbanding of their alliance and the north-Atlantic bloc and, as a first step, for the elimination of the military organizations of the alliances. However, as long as NATO and the danger threatening peace in Europe and the world exist, the socialist countries will be strengthening their alliance and taking appropriate measures to keep their collective defensive ability at a suitable level, simultaneously stepping up the struggle for disarmament, peace and the elimination of military blocs. The Warsaw Treaty member States do not seek to gain military superiority, but do not allow others to gain military superiority over them.

The Warsaw Treaty member States will intensify efforts to avert a nuclear catastrophe, to stop the extension of the arms race to outer space, to stop the arms race on the earth, to radically reduce and finally eliminate nuclear weapons, to ensure the balance of power at the lowest possible level, to change over to disarmament, to make sure that the all-European process is maintained in the spirit of the Helsinki Final Act, and to establish comprehensive and reciprocally beneficial international co-operation based on equality.

The representatives of the Parliaments of the Warsaw Treaty member States met in Budapest in the days when the peoples of Europe and the world are solemnly commemorating the 40th anniversary of the great victory over fascism. Concerning the decisive role of the Soviet people in the destruction of fascism, and the importance of the self-sacrificing struggle of the peoples of the anti-fascist coalition and many other countries, they emphasized: the innumerable victims, incalculable destruction and hard lessons of the Second World War persistently demand the unity of all peoples and States, and all peace-loving forces in the interest of preserving the peace of our world and saving human civilization. In this context the participants of the meeting welcomed the call of the CPSU Central Committee, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the Soviet Union addressed to the "peoples, parliaments and governments of the world" on the occasion of the 40th anniversary of the end of the Second World War to undertake active common actions in the name of stable and lasting peace.

The participants of the meeting expressed their firm conviction that the parliaments and parliamentary representatives of all States can and must take an active part in the struggle to eliminate the danger of a nuclear world war, to pursue a constructive dialogue and co-operation to establish an atmosphere of confidence, and to improve the international climate. This is particularly important today when the forces that expand their arsenals, prepare for the militarization of outer space, continue the policy of military threat and revanchism, query the territorial-political realities of post-war Europe, and overtly interfere with the internal affairs of independent countries are becoming more active.

The representatives of the Parliaments of the Warsaw Treaty member States once again call on the parliaments and parliamentary representatives of Europe and the world to overcome their differences of view, be partners in the struggle to avert the danger of nuclear annihilation, and to pursue broad international co-operation in the interest of maintaining general peace and security.

The meeting was held in the spirit of comradeship, fraternal friendship and full understanding.

CONFERENCE ON DISARMAMENT

CD/623
26 July 1985

Original: ENGLISH

LETTER DATED 18 JULY 1985 ADDRESSED TO THE PRESIDENT OF THE
CONFERENCE ON DISARMAMENT FROM THE CHARGE D'AFFAIRES OF THE
PERMANENT MISSION OF THE ISLAMIC REPUBLIC OF IRAN

Upon instructions from my Government, I have the honour to bring the following to your attention.

The criminal régime of Iraq in continuation of its illegal use of chemical weapons in war, made further resort to the use of those banned weapons against the Forces of the Islamic Republic of Iran, on 7 and 8 May 1985.

The use of chemical weapons on 7 May 1985 was carried out by firing mortar shells against the Iranian Forces stationed in an area north-east of Basra, and the incident on 8 May was against the Forces in Kenareh, south-west of Sardasht employing artillery shells filled with lethal chemicals. As a result of these recent uses of Chemical Weapons a number of Iranians were injured.

These criminal actions, on the part of the Iraqi régime has been condemned by the International Community on several occasions in the recent past but the régime in question has given no heed to the serious concerns of the world community.

Please be kind enough to regard this letter as an official document of the Conference on Disarmament and allow for its circulation accordingly.

(Signed) Farhad SHAHABI SIRJANI
Chargé d'Affaires a.i.

CONFERENCE ON DISARMAMENT

CD/624
26 July 1985

Original: ENGLISH

FEDERAL REPUBLIC OF GERMANY

A System Design for the Gradual Improvement of Seismic Monitoring and
Verification Capabilities for a Comprehensive Nuclear Test Ban

The present study constitutes a supplement to Working Paper CD/612 which, in part C, includes a summary of this scientific paper.

The Government of the Federal Republic of Germany acknowledges assistance in the preparation of this study by the Deutsche Geophysikalische Gesellschaft, in particular:

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PART A: SUMMARY

The objective of this paper is the incremental upgrading of the experimental data exchange system as used during the Group of Scientific Experts Technical Test in 1984 with a view to establishing a functioning, permanently available monitoring and verification system.

The capability of the system to detect and identify explosions would be gradually increased as the system is conceptually and technically improved. Improved system operation characteristics would come about in a sequence of phases. Each phase would be characterized by a different degree of sophistication as far as technical equipment and standardization of operation is concerned and would allow for verification at different levels of magnitude or respective yield levels. Due to inadequate calibration data on source environments and source-receiver paths, magnitude levels can be correlated to yield values only within a relatively broad range.

The approach used in this section distinguishes between verification on a global and a regional level.

The international data exchange system would operate on a global scale and its establishment and operation would be the responsibility of both non-nuclear-weapon and nuclear-weapon States.

In-country networks, consisting of several interrelated stations or arrays, on the other hand, would have to be the subject of separate arrangements among nuclear-weapon States which would include specifications on test sites and calibration parameters to allow for as high a degree of confidence as possible in verification efforts. The calibration data exchanged or collected among the nuclear-weapon States would be made available to non-nuclear-weapon States, thus adding a desirable degree of redundancy to the verification system.

Use of Verification Capabilities of Existing Seismic Installations

In a base model a monitoring network of 50 to 100 stations, as specified by the GSE, would comprise existing seismic stations, existing lines of communication, and existing facilities for the collection, analysis, and dissemination of seismic data. This network, called GSE network below, would by and large correspond to the global seismic data exchange system as operated during the 1984 test run.

It is estimated that the level of verification of this system would equal a magnitude of roughly 5.0 (mb). This corresponds to a yield of approximately 100 kilotons (kt), in the event that seismic signals of explosions are muffled by virtue of dry unconsolidated rock. In wet hard rock the corresponding yield can be as low as 10 kt. These relations can be considered as indicating an upper and lower yield limit for a given magnitude.

A network that would meet these specification could be operational after a period of about two years.

Station operation and maintenance would be provided by the countries hosting the seismic facilities.

System upgrading:

- The international data exchange system would be operated in an extended test mode based on experience from the 1984 GSE technical test. International Data Centers (IDCs) would be set up and operated in specified countries. The data reported by this system would be limited to the basic parameters of detected seismic signals (Level I data). A network of stations based on an appropriate geographical distribution of existing facilities would be defined and incorporated into the monitoring system as much as possible. Fully analysed data would be distributed within one week.
- The GSE would develop detailed specifications for stations that are to participate in the future monitoring network. These specifications would include agreed technical characteristics of the sensors, electronics, and recording equipment, as well as the minimum acceptable site characteristics. Where desirable, all of the data from these dedicated stations would incorporate a data authentication scheme.
- Prototypes of the dedicated stations would be tested and installed at a number of locations.
- Test runs would be conducted by the GSE for the rapid exchange of seismic waveform data (Level II data) in order to promote the practical availability of this technology.

Improvement of Teleseismic Verification Capabilities

Once in operation, the basic international seismic monitoring system would be gradually refined and its capability to detect and identify explosions improved.

By using the inherent capabilities to full extent the verification capability of the GSE network could be upgraded to a level of magnitude 4.7 (mb), which corresponds to a yield of 50 kt and would encompass the possibility of detecting and identifying muffled seismic signals that result from detonations of this yield in dry unconsolidated rock. In comparison the equivalent yield for a magnitude 4.7 (mb) explosion in wet hard rock could be as low as 5 kt.

In essence, the verification system would consist of the GSE network, however, it would contain additional stations and would be operated on an improved technical level.

Further system upgrading includes:

- All dedicated stations, operating by standardized specifications, would be installed at those locations which meet the system design criteria for optimal global coverage.
- Operation of International Data Centers would include exchange of Level II data on a routine basis. Data would be made available and distributed by IDCs.
- Modern telecommunication systems or real-time communication by satellite would be set up for transmission of data within the international seismic data exchange system.

These improvements should bring the verification capability of the global seismological monitoring system to a level of magnitude 4.0 (mb) which corresponds to a yield of 5 to 10 kt taking into account the possibility of muffled signals from explosions in dry unconsolidated rock or to a yield of about 1 kt for explosions in wet hard rock.

For obvious reasons, time-frames are difficult to set with precision. However, these improvements in verification capability could well be achieved after periods of approximately four and eight years, respectively, from the time the continuous operation of the international data exchange system is initiated.

Implementation of In-Country Networks

In addressing the verification capability of a seismic monitoring system particular importance must be attached to the possibility of evading detection by decoupling explosions in a cavity.

The implementation of internal networks, in particular in the territory of nuclear-weapon States, would effectively improve the verification capability by lowering the verification level - within the region - to magnitude 3.0 (mb). This would offer realistic possibilities for detecting and identifying evasion attempts involving yields of 10 kt or greater.

The detection and identification of evasion attempts down to the level of 1 kt would obviously require a much larger technical input. In-country networks with borehole stations or arrays spaced over distances of 500 to 1,000 km - in areas where cavity decoupling is possible - would appear to meet these requirements.

System upgrading:

- In the in-country networks the installation of additional arrays or borehole stations would be continued until the envisaged level of verification is achieved.
- Data on important geological and geophysical parameters as well as other data required for calibration purposes would be exchanged.
- Real-time communication by satellite and modern telecommunication systems would allow IDCs full access to the data from arrays and dedicated stations.

PART B: DESIGN AND ASSESSMENT OF A SEISMIC SYSTEM FOR
MONITORING UNDERGROUND NUCLEAR EXPLOSIONS

1. Introduction

Most intellectual contributions to a seismological verification system so far have visualized the functioning of such a system only within the framework of a full-fledged Comprehensive Nuclear Test Ban Treaty (CTBT). By contrast, the purpose of this paper is to propose the establishment and continuous operation of an international monitoring and verification system based on seismological technology at the present stage, well before the conclusion of a CTBT or other related contractual arrangements, which would continue to unfold under a treaty régime.

In a first phase, the international seismic data exchange system, as tested during two months in 1984, should be put into operation on a permanent basis. In subsequent phases, this system should be gradually improved in a learning-by-doing-process, and brought to a standard which would match the specifications of the most advanced network as described in the first report (CCD/558, 1978) of the GSE, eventually even surpassing it. While efforts to agree on a CTBT continue, an increasingly sophisticated seismic verification system would mature to meet the verification requirements of all parties concerned, so as to be fully operational at the time of the signing of a CTBT. In a dynamic interaction of theoretical development and practical experience, the scientific community could strive to resolve the remaining problems of a verification system in all its aspects: system operation, network detection and identification capability, magnitude-yield estimation, and evasion possibilities.

The gradual development of such a verification system is outlined below.

2. Yield-magnitude Relations

The body-wave magnitude m_b was originally introduced to measure the strength of earthquakes based on P wave signals in the far field. This concept has also been used to estimate the yields of underground nuclear explosions. General regression formulas, such as

$$m_b = c_1 \log W + c_2 \quad (W = \text{yield in kt TNT equivalent})$$

have been widely discussed. Explosion yields cannot be calculated directly from seismic signals, but have to be estimated in relation to a nearby calibration explosion of known yield. In the absence of calibration explosions for most test sites it is impossible to derive accurate yield estimates even for well recorded events.

The strength of a seismic signal, i.e. the magnitude, strongly depends on the medium in which the explosion is detonated. Explosions in hard rocks, like granite, or tuff give considerably stronger signals than the explosions in unconsolidated rocks such as alluvium. When the explosion is located above or below the water table, i.e. in dry or wet material, further differences in seismic amplitudes appear.

In the following we have used a published magnitude-yield relation (Murphy, 1981) which is based on data from the United States test site in Nevada (Fig. 1).

$$(1a) \quad mb = 3.92 + 0.81 \log W \text{ (hard wet rock)}$$

$$(1b) \quad mb = 3.32 + 0.81 \log W \text{ (dry unconsolidated rock)}$$

These relations can be considered as giving an upper and lower yield limit in kilotons for a given magnitude.

Seismic signal strength depends not only on the explosion yield and the shot medium, but also on the wave transmission properties of the earth. These properties vary considerably for different source-receiver paths. Including all these effects into the variance of the regression curves of Fig. 1, the range of yield uncertainty would be a factor of about 10. Taking this uncertainty into account we correlate magnitude 5.0 (mb) roughly with 100 kt (118 kt from equation (1b)) in dry unconsolidated rock and with 10 kt (21 kt from equation (1a)) in wet hard rock.

For magnitude 4.7 (mb) these values are simply decreased by a factor of two giving 50 kt in dry unconsolidated rock and 5 kt in wet hard rock.

Finally we will discuss in this study a global network with a verification capability of the magnitude 4.0 (mb) level which we correlate with 10 kt (7 kt from equation (1b)) in dry unconsolidated rock and with 1 kt (1.25 kt from equation (1a)) in wet hard rock.

Seismic signals from an explosion can also be reduced by detonating the explosion in a large, underground cavity. This method can be used for the purpose of evasion and will be discussed in detail in part C of this study. Such cavities must be constructed in hard rock, like granite, or salt. From theoretical calculations (to be shown in part C) follows a maximum decoupling factor of 200, which decreases a 10 kt explosion to a fictitious tamped 50 t explosion. Using relation (1a) we derive an equivalent magnitude of 2.9 (mb). Explosions in salt are inferred to couple more efficiently, resulting in an estimated mb-yield curve which is offset above the granite curve by as much as 0.5 units mb. Because of the cavity size needed for full decoupling explosions in the order of 10 kt are regarded to be about the upper technically feasible yield limit. Decoupled explosions of this size can be monitored by regional networks with verification capabilities at magnitude 3.0 (mb) level. To monitor decoupling attempts of 1 kt explosions resulting in a fictitious tamped 5 t explosion, dense regional networks would be needed as outlined later in part C. Because the body-wave magnitude mb concept breaks down for close source-receiver distances we will discuss this verification level in terms of signal amplitude decay and adequate station spacing instead of mb-yield correlation.

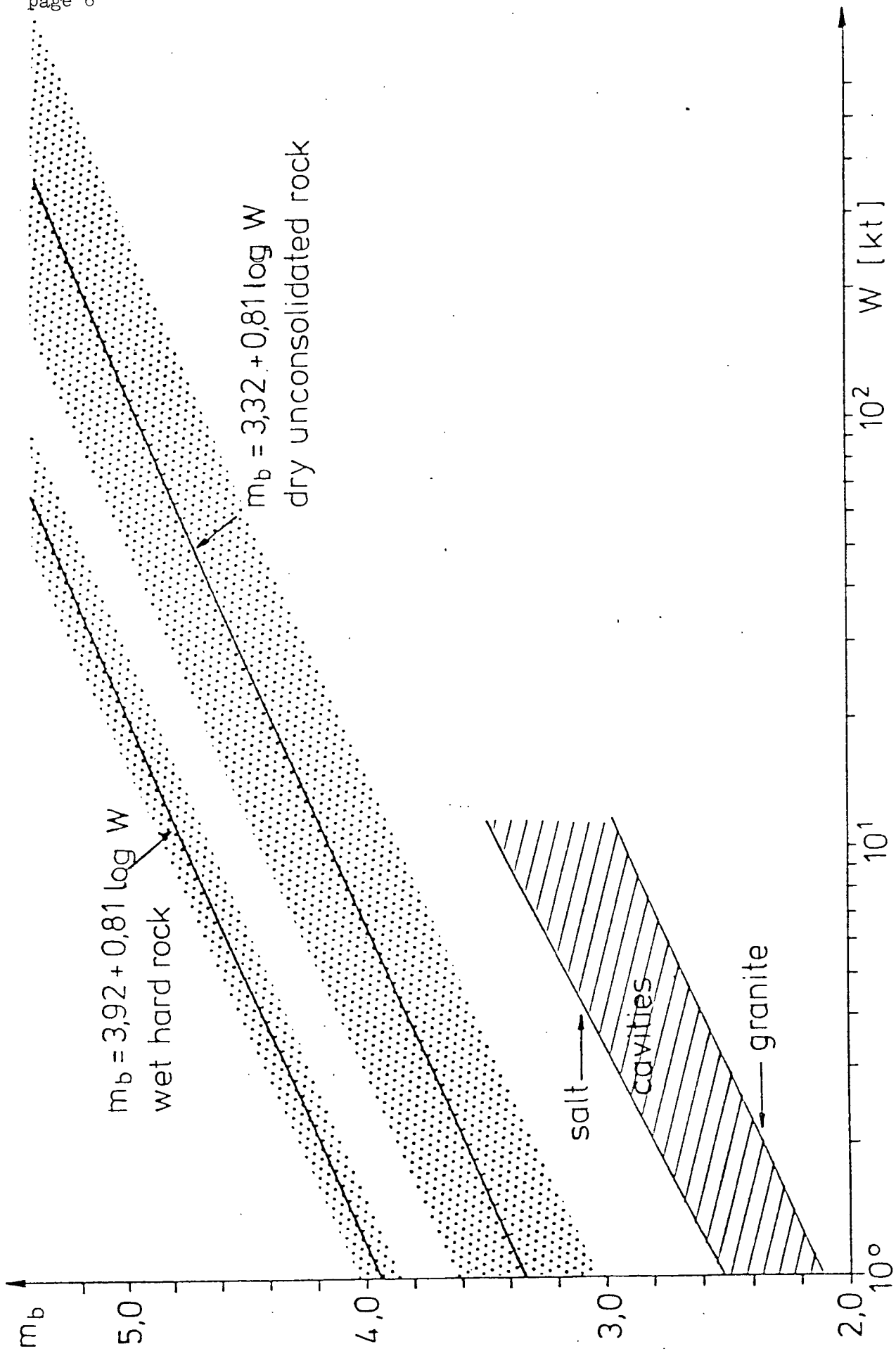


Fig. 1: Seismic body-wave magnitude m_b versus yield for different explosion environments. The relationships are based on NTS data.

3. Verification Capabilities of Global Seismic Systems

At the beginning the seismic monitoring system called phase 1 system would be based on existing seismic facilities as used during the 1984 GSETT. In this experiment, conducted for two months between 15 October and 14 December, altogether 79 seismic stations in 38 countries intended to participate. For the purpose of this study we selected those stations which reported a minimum number of level 1 parameters for at least 10 events. Besides amplitude and period of P wave, short-period and long-period noise data were used as a selection criterion. Starting from the bulletin published by the Swedish Data Center in Stockholm immediately after the end of the experiment we thereby found 47 stations of which the geographical distribution is shown in Fig. 2. Station codes, geographic co-ordinates and noise estimates are given in Table 1.

Three experimental International Data Centers (EIDCs) were operated at that time by Sweden, United States of America and USSR. For exchange of seismic data between national facilities and the EIDCs as well as among the data centres themselves, the world-wide channels of the WMO/GTS (World Meteorological Organization Global Telecommunication System) were used. The technical test had the following purposes (CRP.134, 1984):

- to develop and test procedures (with the WMO) for the regular transmission of Level I data from temporary national facilities to experimental international data centres (EIDCs);
- to transmit bulletins from EIDCs to participating temporary national facilities using the WMO/GTS;
- to test procedures for retransmission of Level I data messages over the WMO/GTS;
- to provide an opportunity for testing procedures for extracting Level I parameter at seismic stations;
- to develop and test procedures for transmission of Level I parameters to temporary national facilities;
- to test proposed procedures at EIDCs for receipt and archiving of Level I data and for compilation and distribution over the WMO/GTS of event bulletins and parameters using Level I data.

Changed from methodical to routine operation the objectives of the Technical Test would in essence meet the requirements of a seismic monitoring system in its first phase and therefore, could immediately become operational.

Within a two year period it should be possible to improve successively the performance of the system as well as to overcome those difficulties that were revealed during the 1984 experiment. This holds especially for procedures used at EIDCs with respect to

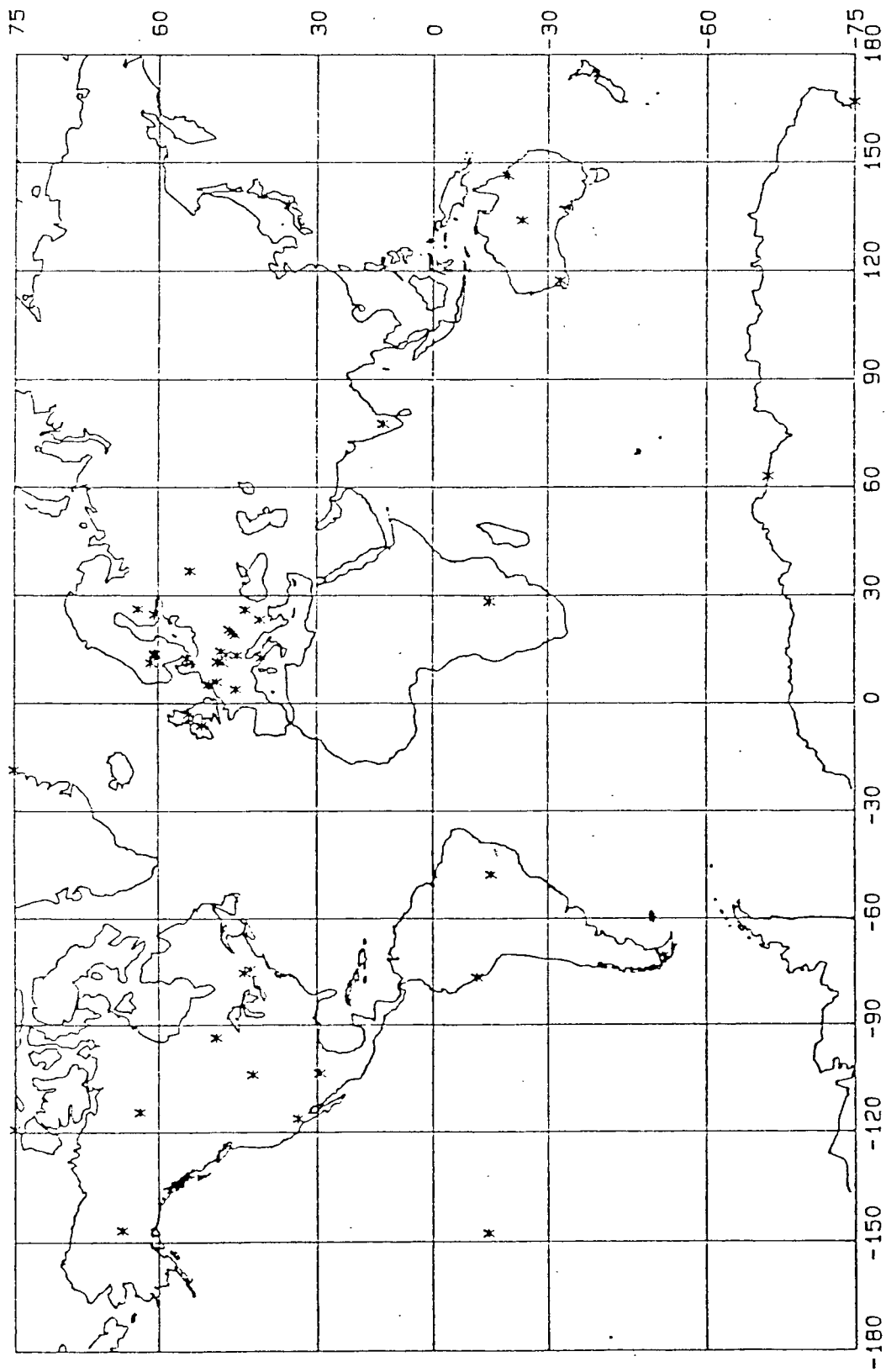


Fig. 2: 47-station GSETT network

Table 1: Station codes, coordinates and noise statistics
for GSETT network

i	station code	lat.	long.	SP-noise		LP-noise	
				ampl [nm]	sd [mb units]	ampl [nm]	sd [Ms units]
1	apo	60.54	13.93	1.58	0.40	153.00	0.30
2	aspa	-23.67	133.90	0.91	0.27	107.00	0.30
3	bdf	-15.66	-47.90	60.26	0.67	400.00	0.30
4	bud	47.48	19.02	31.62	0.20	200.00	0.30
5	cop	55.68	12.43	58.88	0.26	262.00	0.30
6	ctao	-20.09	146.25	3.09	0.21	99.00	0.30
7	dag	76.77	-18.65	3.63	0.15	200.00	0.30
8	dbn	52.10	5.18	5.75	0.25	289.00	0.30
9	dkm	53.26	-6.26	77.62	0.27	200.00	0.30
10	eka	55.33	-3.16	2.19	0.24	57.00	0.30
11	enn	50.77	5.92	4.57	0.30	200.00	0.30
12	fbas	64.77	-146.89	2.19	0.26	58.00	0.30
13	gac	45.70	-75.48	3.72	0.25	49.00	0.30
14	gba	13.60	77.44	3.02	0.12	157.00	0.30
15	grf	49.69	11.22	5.50	0.10	166.00	0.30
16	hfs	60.13	13.70	1.70	0.48	93.00	0.30
17	jos	48.50	20.54	3.02	0.20	200.00	0.30
18	kba	47.08	13.34	2.45	0.26	200.00	0.30
19	khc	49.13	13.59	3.39	0.14	330.00	0.30
20	lac	34.39	-116.41	1.66	0.29	346.00	0.30
21	lor	47.27	3.85	1.55	0.19	40.00	0.30
22	lsz	-15.28	28.19	2.00	0.26	200.00	0.30
23	ltx	29.33	-103.67	0.70	0.29	223.00	0.30
24	mat	36.54	138.21	7.24	0.17	267.00	0.30
25	maw	-67.60	62.87	1.12	0.26	200.00	0.30
26	mbc	76.24	-119.36	3.60	0.24	128.00	0.30
27	mlr	45.49	25.94	3.98	0.23	200.00	0.30
28	mns	42.39	12.68	5.01	0.11	200.00	0.30
29	mox	50.65	11.62	3.31	0.17	235.00	0.30
30	nb2	61.04	11.21	0.42	0.15	97.00	0.30
31	nna	-11.99	-76.84	12.30	0.39	400.00	0.30
32	nur	60.51	24.65	6.76	0.17	120.00	0.30
33	nwao	-32.93	117.23	1.32	0.13	145.00	0.30
34	obn	55.12	36.60	15.14	0.20	200.00	0.30
35	pmo	-15.00	-147.90	14.10	0.30	400.00	0.30
36	pru	49.99	14.54	6.31	0.22	133.00	0.30
37	psz	47.92	19.89	6.76	0.29	200.00	0.30
38	rsny	44.55	-74.53	9.33	0.35	141.00	0.30
39	rson	50.86	-93.70	3.16	0.19	89.00	0.30
40	rssd	44.12	-104.04	2.40	0.23	93.00	0.30
41	sba	-77.85	166.76	4.90	0.20	400.00	0.30
42	sll	60.48	13.32	2.57	0.38	139.00	0.30
43	suf	62.72	26.15	1.12	0.27	200.00	0.30
44	tby	60.08	12.83	1.23	0.14	200.00	0.30
45	vtc	42.60	23.20	1.78	0.30	200.00	0.30
46	wel	-41.29	174.77	85.10	0.20	400.00	0.30
47	yka	62.49	-114.61	1.23	0.27	151.00	0.30

- the use of different algorithms for event association;
- the inclusion of long-period parameters in the compilation of seismic bulletins;
- the lack of communication (other than via the WMO/GTS) between IDCs, resulting in lack of comparison of Level I data archives, and, less important, redundant but confusing transmission requests.

Apart from routine system operation on the basis of improved instructions elaborated by the GSE, the network should be extended to achieve a more equal coverage of the globe by including and/or deploying additional seismic stations on the Eurasian continent and in the southern hemisphere.

As far as the technical standard of the stations is concerned, efforts should be made to successively replace analog recording facilities by digital equipment as well as to intensify the use of digital data processing and analysis techniques at national facilities. With regard to these points the GSE should work out detailed specifications for seismic stations to participate in the monitoring networks in the follow-up phases. These specifications further described in chapter 4 would include agreed technical characteristics of the seismic sensors, electronics, and recording equipment, as well as minimum acceptable site characteristics.

Further activities of the GSE should concentrate on the development of methods for rapid exchange of seismic waveforms (Level II data). For testing the procedures, multilateral experiments should be carried out using available channels of modern telecommunication systems including satellite connections (see chapter 5).

3.1 System performance

In seismological terms the capability of a seismic verification system is expressed by the lowest mb-magnitude of a seismic event that is estimated to be detected, located and identified. The estimation technique will be described in some detail for phase 1 system.

With regard to nuclear explosions magnitudes can be converted to yield on the basis of available magnitude-yield relations including data from calibration explosions as outlined in chapter 2.

3.2 Detection capability

For the assessment of network detection capability different methods are used. The analysis of Davies (1969) contained in the SIPRI report as well as of Basham and Witham (1970), Elvers (1978) and that given by the GSE in the first report to the Committee on Disarmament in Geneva, (CCD/558, (1978)) are conceptually based on a straightforward statistical estimation model. For a given network of seismic stations with known background noise level, a set of epicenter locations and standard amplitude-distance attenuation curves for seismic waves, the detection capability is expressed by the magnitude corresponding to a fixed probability that a specified minimum number of stations detect an event.

Another method found in a paper of Kelly and Lacoss (1969) and in a GSE working paper of the United States (US/GSE/7, 1980) takes average world-wide seismicity into account. Using known earthquake recurrence rates, a synthetic list of events is produced as a reasonable approximation to those actually observed in a specific time interval. If station parameters are kept unchanged this method allows an independent check on the results of studies mentioned previously.

A third procedure is based on real data collected during special experiments as for example during the ISM (International Seismic Month, Lacoss (1974)) or routinely by international agencies (e.g. International Seismological Centre (ISC), Newbury, U.K.). Estimates of network detection thresholds are obtained using the recurrence method or maximum-likelihood techniques (Ringdal et al. (1977), Ringdal (1984)).

Estimates of detection capabilities of seismic networks differ substantially as a result of these approaches. In general, the detection threshold increases in the order of the described procedures. The reason for this is partly due to the difference between operational station performance used in the last approach and the idealized assumption based on pure noise statistics which are input to the method described first. With respect to the network of phase 1 it is possible to check the two methods against each other. This can be done using the noise data reported during the Technical Test as input for the statistical approach and comparing the results with empirical detection thresholds on the basis of the recurrence curve estimation method. It should be noted that the latter method is only applicable for a few regions where the number of events recorded during the GSETT was sufficiently high.

The detailed technical background of the calculations for estimating network detection capabilities of the GSETT network as well as of other models presented in this paper are given in Harjes (1985), Ciervo et al., (1983), Wirth (1977) and Elvers (1980).

The basic input parameters that are to be specified at the beginning are

- Seismic station locations and their noise statistics (mean and variance).

For the GSETT network noise data were estimated from short-period and long-period noise amplitudes reported by stations participating in the test. Station names, geographical co-ordinates and noise parameters are given in Table 1.

- Amplitude-distance relations for seismic phases.

We used the attenuation curve for P and PKP waves in Fig. 3 which was derived from ISC data for the NORSAR array (Ringdal and Fyen, 1979). This curve was smoothed at regional distances and we especially omitted the amplitude anomaly around 20 deg. It was found (Harjes, 1985) that the results for a global network systematically depend on the type of P wave attenuation function, if for example other curves published by Gutenberg-Richter (1956), Everden-Clark (1970) or Veith-Clawson (1972) are used. There is a major effect from extending the attenuation curve beyond 100 degree distance to include PKP phases as will be discussed later.

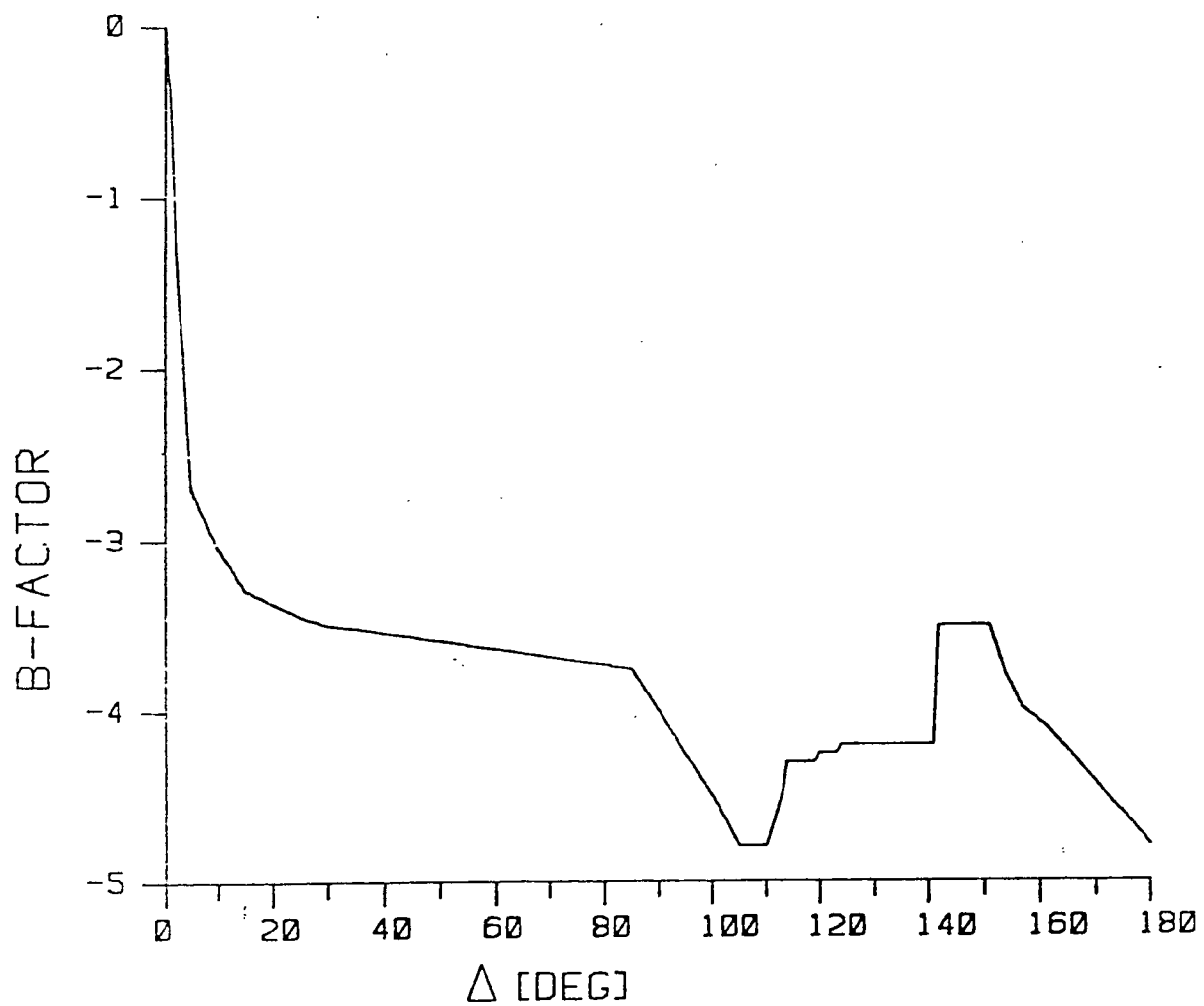


Fig. 3: Amplitude-distance attenuation curve for P- and PKP-wave amplitudes.

- Signal-to-noise ratio required for detection of P or PKP waves. The S/N ratio strongly depends on the station operation. As long as at a majority of stations events are detected by visual inspection, a conservative estimate of $S/N = 3$ is used. When automatic detectors are generally implemented, the S/N ratio could be lowered to a value of 1.5 which would consequently lower the detection threshold by 0.3 magnitude units.
- The detection criteria define the minimum number of stations which are necessary to detect an event.

Theoretically, four stations are needed to locate an event. In phase 1 system, we require for at least eight stations to declare an event to be detected. This takes into account occasional non-functioning of some stations and reflects the experience from the GSETT.

On the basis of these input data 90 per cent detection probability of the GSETT network was calculated in terms of mb-magnitude. Fig. 4 shows the detection threshold for a grid spacing of 15 degrees.

A large geographical variation of about one magnitude unit in detection capability ranging from 3.8 to 4.9 can be seen. This partly results from the heterogeneous station distribution but also from the high noise values which were reported by most of the stations in the southern hemisphere.

Comparing these results with empirical detection probabilities derived on the basis of the recurrence estimation method, the magnitudes are fairly similar. In Fig. 4 the mb values within the circles refer to those areas for which the data base of the GSETT permitted this kind of analysis with some confidence.

Anyhow, the results reveal that even under test conditions world-wide detection of magnitude 5.0 (mb) events could easily be accomplished with this network. According to chapter 2 this corresponds roughly to a yield of 10 kt in water saturated hard rock or to a yield of 100 kt, assuming a detonation in unconsolidated dry rock.

3.3 Location capability

The accuracy of seismic event location is important in context with monitoring underground nuclear explosions as longitude and latitude and, in particular depth are fundamental identification parameters. More than 90 per cent of all earthquakes occur under oceans and/or at least below 30 km (Sykes et al., 1983), i.e. in areas where testing of nuclear devices is at present assumed to be technically impossible. Moreover it is essential to know whether an epicenter lies within the borders of a certain country and, in the case of a nuclear weapon State, inside or outside a certain test area.

As has been stated earlier, at least four stations are needed to locate an event. Accuracy of epicenter determination depends critically on the number of stations that detect the event. Consequently the location capability will

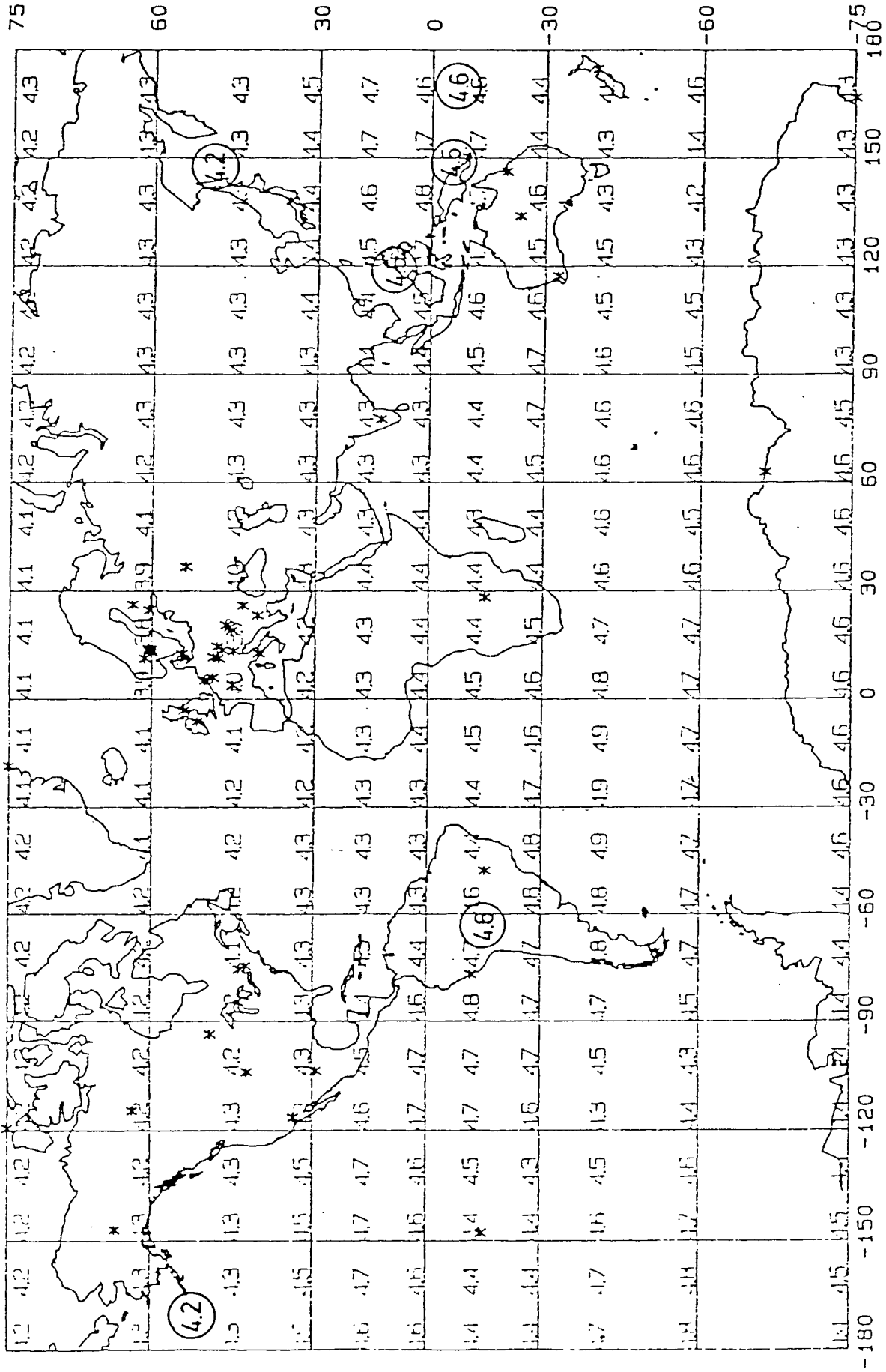


Fig. 4: GSETT network detection capability corresponding to a 90% probability (at 8 detecting stations or more) with a signal-to-noise ratio of at least 3.0 in terms of mb-units. Calculations of mb are based on amplitude-distance corrections from Fig. 3.

decrease with decreasing magnitude. On the basis of these conditions the achievable location accuracy for an event of magnitude 5.0 as well as of 4.0 was calculated. The results are shown in Figs. 5 and 6. The numbers at the grid points denote the major axis of the estimated 95 per cent confidence location ellipse in kilometers for a hypothetical epicenter of an event of the given magnitude.

At the envisaged verification level of magnitude 5.0 (mb) the location accuracy of phase 1 system varies between 20 km and 40 km. The location error increases to 40 km - 100 km for small events (mb = 4.0). Such general estimates of location accuracy must be considered as order-of-magnitude estimates, because only stochastic errors are considered in this model. The real location errors might be considerably larger due to systematic differences between the travel-time model and the real earth. These errors can only be disclosed by calibration events with known epicenter co-ordinates.

3.4 Identification

Various methods have been developed and tested in the past to distinguish between seismic signals from underground explosions and earthquakes. The monitoring system should be capable of providing at the earliest possible date all necessary data for any identification scheme. The most prominent methods that should be covered are the following:

- focal depth determination with high accuracy on the basis of standard epicenter determination combined with implementation of secondary phases;
- first-motion sign criterion of short-period and long-period first arrivals;
- Ms:mb criterion;
- Spectral discriminants (complexity, third moment of frequency).

A system as operated during GSETT would be completely based on Level I parameters extracted from the recordings of teleseismic signals. These discriminants are part of the complete set of Level I data listed in the reports of the GSE to the CD (CCD/558, (1978), CD/43, (1979)). According to the instructions for extraction of Level I data at a three-component station of short- and long-period seismometers, these data comprise more than 50 different parameters. The workload for measuring the data for all recorded events is considerable, although data from digital stations can be determined by automated and/or interactive procedures.

The volume of Level I data generally increases with the strength of the seismic events as the seismograms contain various phases which have to be reported. In contrast to this, only a few parameters can be extracted from signals of small events which are much more difficult to identify. Considering that 90 per cent of the seismic events can immediately be declared to be earthquakes as soon as the epicenter and focal depth are known, the workload required for extraction of the complete set of Level I data is out of

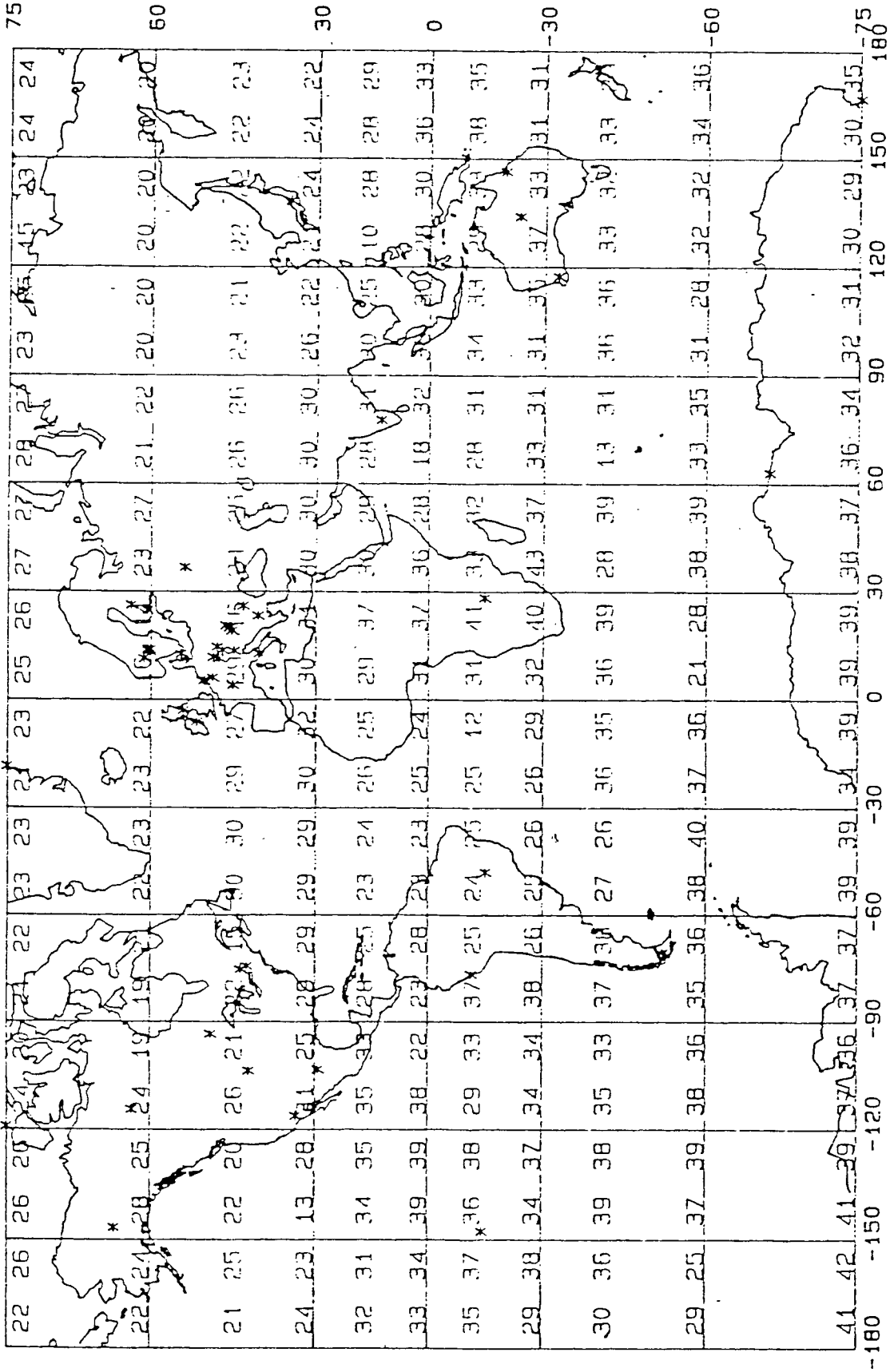


Fig. 5: Location capability of GSETT network for mb=5.0 events

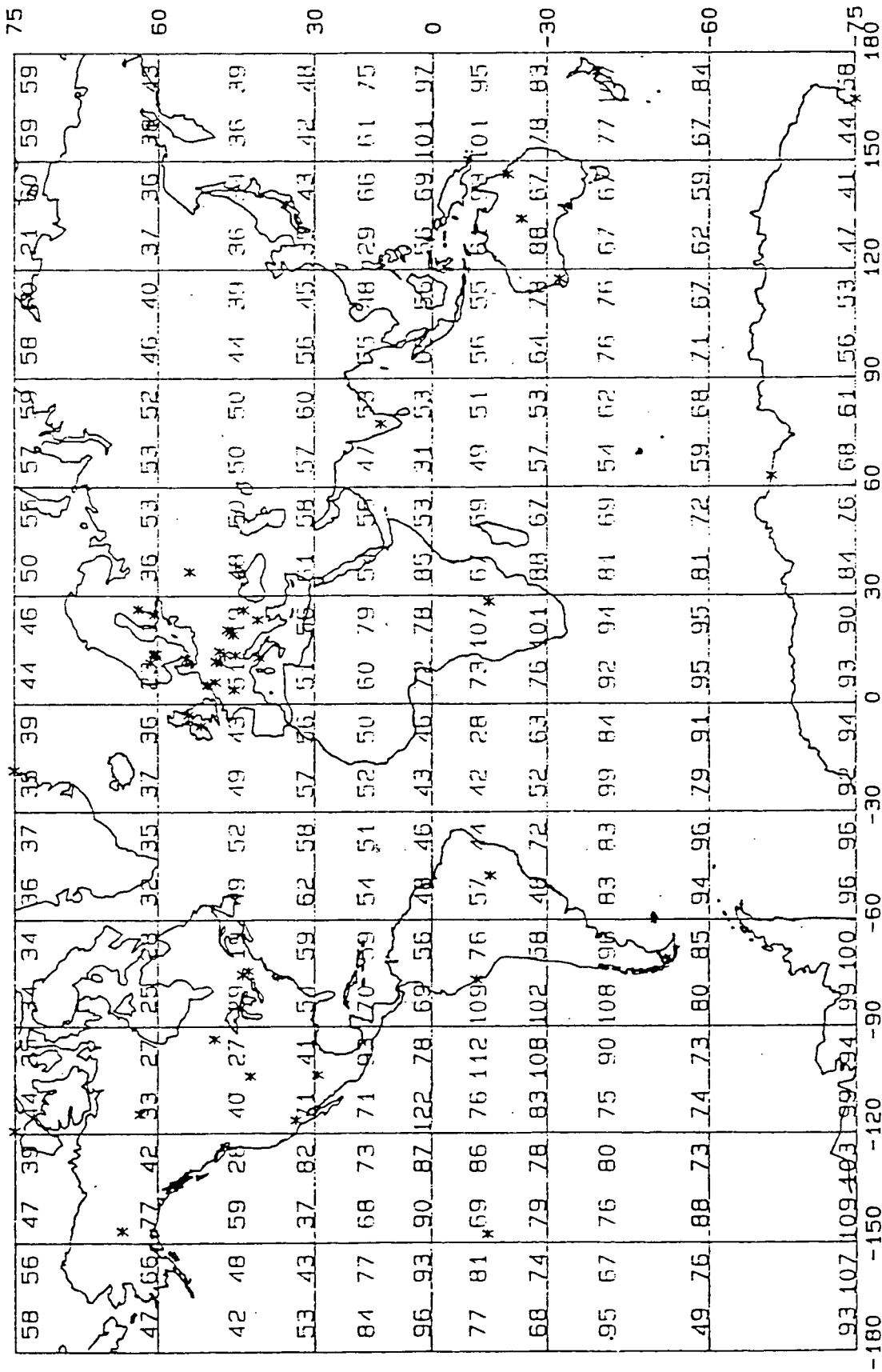


Fig. 6: Location capability of GSETT network for mb=4.0 events

proportion to the usefulness of these parameters. It would be more reasonable to determine routinely a subset of the data needed for locating the event and as a second step to exchange the seismograms (Level II data) in case of suspicious events. On the basis of these data any discriminant that promises to be most effective for identification could be derived.

The proposed two-step procedure, however, is not applicable at the level on which the GSETT network is operated. In this experiment the majority of participating States reported a subset of Level I parameters called minimum set. In addition to noise amplitudes in the short-period and long-period band these data contained the parameters of the first arrival and of the surface waves of Rayleigh type. Apart from location and depth determination by standard hypocenter determination, minimum set data would allow application of first-motion sign and Ms:mb criterion. For extraction of additional discriminants, in particular spectral parameters, Level II data would be required.

With respect to the Ms:mb criterion the evaluation of the test results revealed that only a small percentage (about 20 per cent) of those events which were defined by P-detections could be amended with long-period parameters. The long-period noise values in Table 1 are estimated from these reported data. For a number of stations they are simply set to 200 nm and 400 nm. The same model as for P waves was now used for Rayleigh waves to find the detection capability of the GSETT network in terms of surface wave magnitude Ms.

Besides the station data from Table 1, the well known "Prague" formula, recommended by IASPEI and its extension to regional distances as given in a previous GSE report (CCD/558, 1978), has been applied for amplitude-distance correction.

$$(2) \quad M_s = \log (2A/T) + 1.66 \log \Delta^\circ \quad \text{for } \Delta \geq 25 \text{ deg.}$$

$$M_s = \log (2A/T) + \log \Delta^\circ + 0.92 \quad \text{for } \Delta \leq 25 \text{ deg.}$$

Fig. 7 shows the detection capability of the GSETT network estimated in terms of Ms units based on 0.9 probability of detection at four or more stations with a S/N ratio of at least 1.5. For most parts of the northern hemisphere we clearly get values below magnitude 4.0 (Ms). In the southern hemisphere the detection threshold for surface waves is increased to magnitude 4.2 (Ms).

As for body-wave magnitude mb there are surface wave magnitude-yield relations from various authors. For our purposes the Marshall et al. (1971) curve seems to be appropriate.

$$(3) \quad M_s = \log W + 2 \quad (W = \text{yield in kt})$$

This relation was derived for explosions in consolidated rock. It is sufficient as a global average estimate. Referred to this curve, a yield of 100 kt correlates to a surface-wave magnitude of 4.0 (Ms).

In fact, we can relax the detection criterion from Fig. 7 because we intend to use the Rayleigh waves for identification and not for detection and location. If a Rayleigh wave detection of two stations and more (instead of four stations and more) is considered to be sufficient, we get a surface wave detection threshold of $M_s = 4.0$ nearly all over the world (Fig. 8).

The poor reporting of long-period parameters during the GSETT can be attributed, even more than for the short-period detection capability, to the fact that some countries concentrated primarily on methodical aspects and less on complete reporting of all seismic events. As soon as the experimental stage of phase 1 has been overcome, system performance will gradually improve. Identification of explosions with a yield of 100 kt is already possible with a high degree of confidence in the very beginning as shown by the results of the GSETT.

3.5 System operation

The seismic verification system at a magnitude 5.0 (mb) level could essentially be operated like the experimental system during the GSETT. The instructions and procedures elaborated and applied during this experiment would be improved on the basis of the test results which are currently being evaluated.

As a main component the system would comprise a network of about 50 seismic stations. Maintenance, station operation and extraction of a minimum set of Level I parameters (Conference Room Paper 134/Rev.1, 1984) of all recorded seismic events would be provided by the national facilities of the participating States. Within one week after recording of an event, the extracted data would be transmitted via the WMO/GTS to at least three International Data Centers. Installation of one or two additional IDCs in the southern hemisphere (Australia, South America, Africa) should be encouraged.

Technical equipment and personnel of an IDC would be provided by State hosting a data center. The operational procedures would be in accordance with the instructions given in the third report of the GSE (CD/448, (1984)). Each country contributing seismic data would have unhindered access to the data archives of each IDC.

Communication and data exchange between IDCs and national facilities should not be limited to the WMO/GTS as during the GSETT but include also other channels as for example telex and telephone lines and, if available, computer links via high-speed communication systems.

Seismic bulletins compiled by the IDCs after reconciliation should be distributed via WMO/GTS with a time delay of at most two weeks after the date of the seismic event. A final bulletin that contains the epicenter data, the complete parameter set reported by the individual seismic stations, as well as the data of unassociated arrivals should be made available to all participating countries one week after transmission of the bulletin containing purely epicenter data.

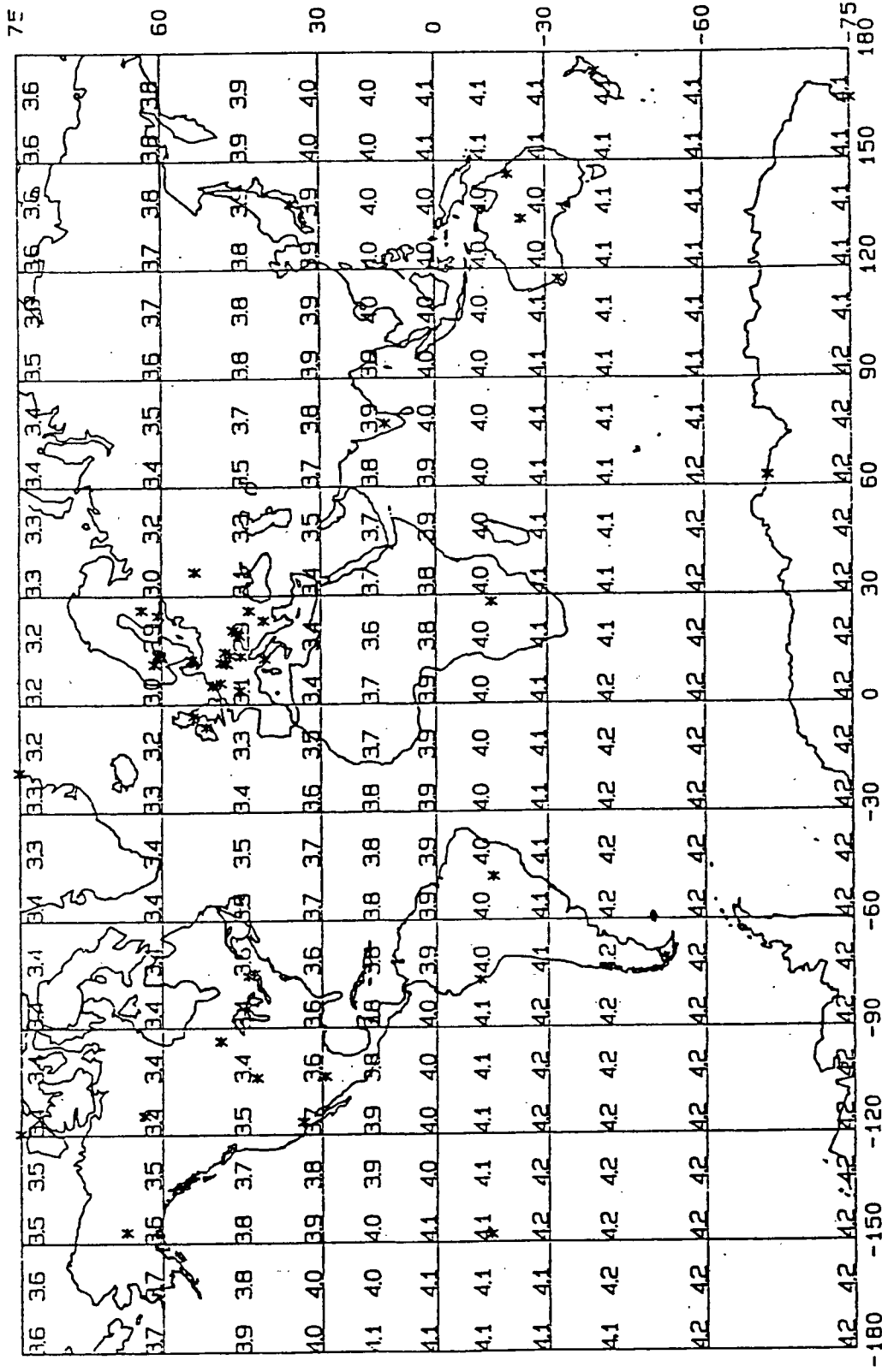


Fig. 7: GSETT network detection capability corresponding to a 90% probability (at 4 detecting stations or more) with a signal-to-noise ratio of at least 1.5 in terms of Ms-units. Calculations of Ms are based on amplitude-distance corrections from equation (2).

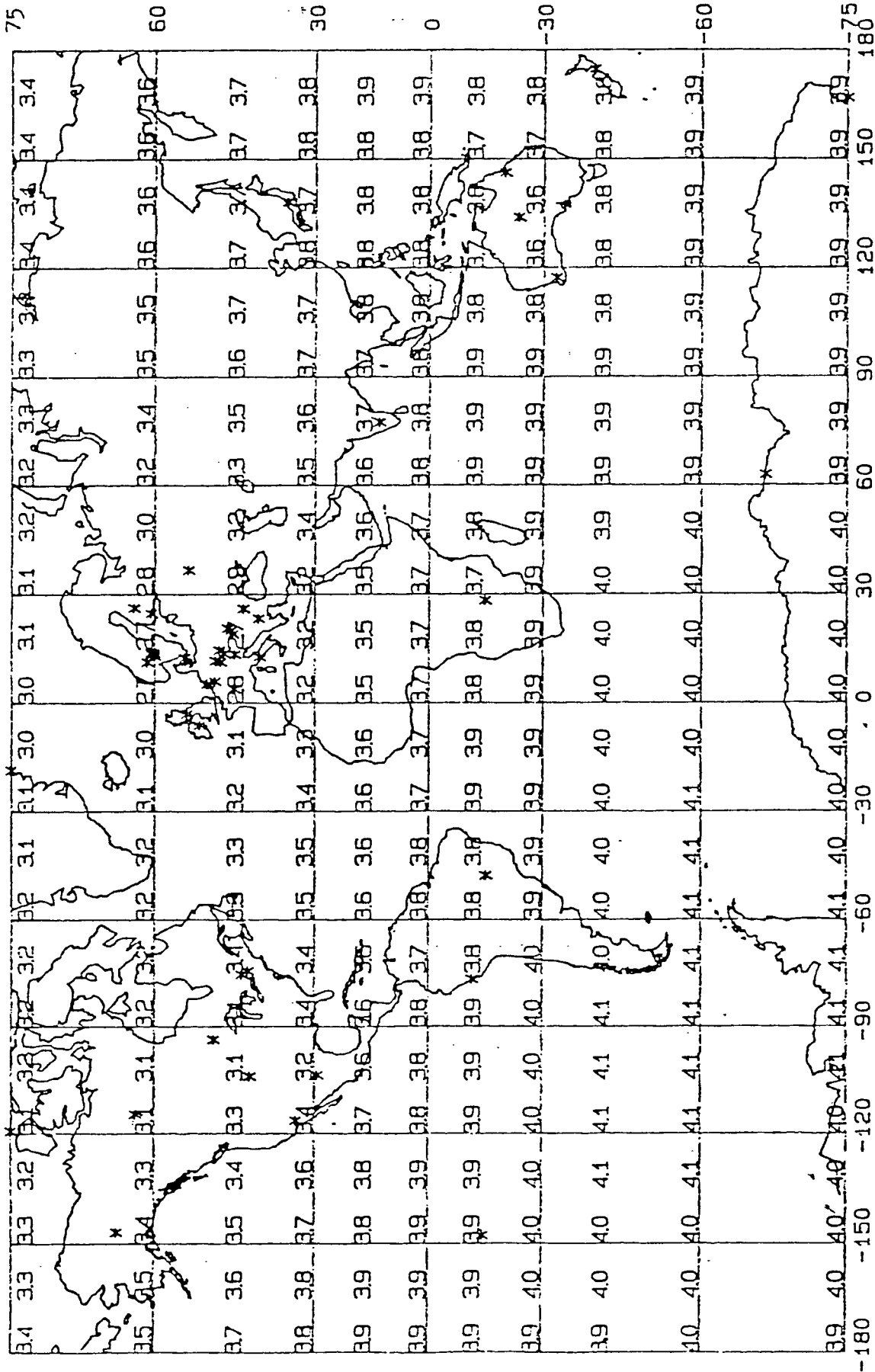


Fig. 8: GSETT network detection capability corresponding to a 90% probability (at 2 detecting stations or more) with a signal-to-noise ratio of at least 1.5 in terms of Ms-units. Calculations of Ms are based on amplitude-distance corrections from equation (2).

4. Technical Design of Future Dedicated Seismic Stations

Seismic stations belong to the most important elements of a global network as their performance determines primarily the capability of the whole system. The technical concept of a prototype station could be similar to that of an "National Seismic Station" (NSS) described by Dahlman and Israelson (1980), however, built up of the most advanced technological components. The stations presently operated in the RSTN (Regional Seismic Test Network, US/GSE/24, (1982)) come very close to this level as they meet in principle the requirements with respect to

- data quality;
- data availability;
- system security;
- reliability;
- maintenance.

Taking recent technical developments into account and following in principle the description of the NSS concept given by Dahlman and Israelson (1980), a dedicated station would consist of the following components:

- a data acquisition system including a primary three-component set of broadband seismometers (e.g. GEOTECH KS-36000), a backup three-component set of short-period seismometers (e.g. GEOTECH S-750) and electronics to filter, amplify, digitize, format and authenticate the data. Seismometer output of the broadband instruments is filtered in three different passbands: a long-period (LP) band (0.01 - 0.1 Hz), a mid-period (MP) band (0.07 - 2 Hz), and a short-period (SP) band (1.0 - 10 Hz). Analog signals of the broadband seismometer outputs are digitized by 24-bit A/D converters, providing a resolution of at least 120 dB at 10 Hz and higher at lower frequencies. Sampling frequency for long-period data is 1 Hz, for mid-period data 4 Hz and for short-period data 40 Hz. This is achieved by a process of oversampling and digital filtering. More details on the various components of an NSS are given by Dahlman and Israelson (1980).

For reduction of seismic background noise the whole data acquisition package is installed in a borehole. If the site is situated on hard rock, a depth of 100 m. will be sufficient whereas 300 m are required in less competent material (GSE/FRG/17, 1984).

- surface installation;

The facilities include "low power" microprocessor systems and different peripheral units for data recording and data transmission. The configuration of the station hardware is shown schematically in Fig. 9. The seismic data stream supplemented by actual time of day as well as station state-of-health information (2,400 bps) is passed continuously in a special mode (digital delay line) to a communications terminal for transmission via satellite to the IDCs. Simultaneously, the data are also stored on magnetic tape in case satellite communication should be interrupted due to failure.

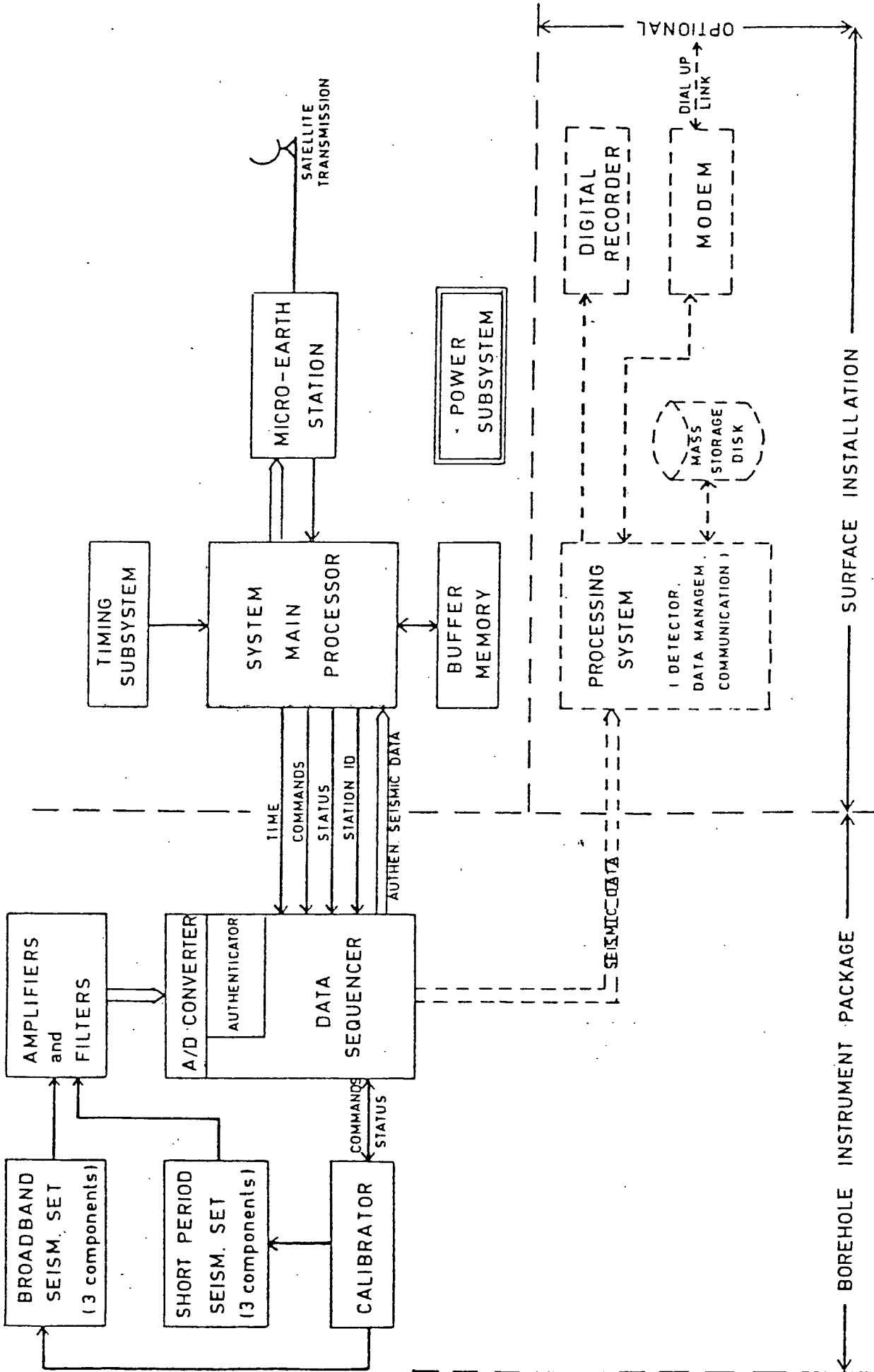


Fig. 9: Block diagram illustrating the principle components of a dedicated seismic station

An alternative to magnetic tape recording is offered by magnetic disk drives which have at present capacities of 600 MB. Data collected in a time period of more than three weeks could be stored in a ring buffer on this medium. Access to any data section of the recorded time period can be provided by any communication channel connected to the system. This must not necessarily be a satellite link but can even be accomplished via a 1,200 bps telephone line. Information on seismic events detected by an automatic event trigger in the three passbands, implemented in the microprocessor system, is also recorded on the disk as a separate file and remotely accessible as well. Normally, data transmission would be restricted to the detection log and to short sections (30 s) of triggered events. Assuming an actual transmission speed of 1/3 of the nominal capacity of a data line, transmission of a data sample of 30 s from a three-component station (40 Hz sampling rate) requires 144 s on a 1,200 bps line. This demonstrates that, even on low-speed data lines, routine transmission of Level II data at an average of 20 events/day would not cause serious problems.

The concept of a station with additional data storage capacity is preferred at stations where electric power would not have to be supplied by electric generators but by the mains, and where satellite transmission is not feasible. For reasons of efficiency the transfer rate of the connected communication line should be as high as possible.

- satellite communications link;

The data are transmitted in real time via satellite to a system control and receiving station operated under control of an IDC. Commands from the IDC to the station would also be transmitted via satellite or, optionally via other data channels.

5. Exchange of Seismic Waveforms (Level II data)

According to the reports submitted to CD by the GSE (CCD/558, (1978), CD/43, (1979), CD/448 (1984)) exchange of Level II data in a future seismic monitoring system will be made, upon request, between national facilities through IDCs. Full agreement was achieved in the GSE with regard to this procedure as well as on the significance of waveform data for identification. Investigations of Barkeby *et al.* (1981) and Bergkvist (1983) moreover proved the usefulness of Level II data at IDCs for event definition and phase association. Nevertheless it was not yet possible to achieve agreement in the GSE on items like

- volume of Level II data to be requested;
- format of digital data to be exchange on magnetic tape or via telecommunication channels;
- standards for protocols for handling data transmission between computers.

Consequently no efforts have been made so far to develop and to test instructions and procedures for exchange of seismic waveforms. We consider the solution of these problems as the most urgent task, since the importance of Level II for locating and identifying seismic events will increase to the same degree as the threshold of the verification system decreases. This is also valid

for the efficiency of IDCs with respect to phase association, epicentre determination and depth estimation. As long as event definition and location is purely based on Level I data, an international verification system will be inferior to systems available to individual countries and, in particular to existing international seismological data centres as for example the NEIS (National Earthquake Information Service, Boulder) or the ISC (International Seismological Center, Newbury).

It has been repeatedly stated by many scientists that exchange and analysis of large volumes of Level II data is no longer a technical problem. Today, technology of computer and telecommunication systems allows rapid and practically unlimited exchange of Level II data with a high degree of reliability. Different communication channels are available and were successfully tested or are in routine use by various countries. Numerous national working papers presented in the GSE and summarized in CD/448 (1984) deal with experience in this field. For transmission of digital seismic data between computers and microprocessor systems on a national, bilateral or a multilateral level, the following telecommunication systems are most common:

- commercial telephone lines (300 - 2,400 bps);
- virtual or dedicated data lines (1,200 - 9,600 bps) of international packet switched networks;
- satellite transmission (max. 90 Mbps) via INTELSAT.

Due to the fact that this technology is not available in some parts of the globe it seems to be realistic that, as a first step, digital stations of the network take part in routine exchange of Level II data, providing, on request, the data at least by mail on magnetic tape. A standard format for the data tapes should be worked out by the GSE, although the IDCs would certainly be able to convert the data to any format required by the State that requested the digital seismogram.

Exchange of digital Level II data by mail will end as soon as data can be transmitted directly to an IDC by means of other telecommunication channels. At the lowest level, telephone lines would be used for data transmission. Data handling would be made on the basis of simple protocols like SAFT or KERMIT that can be made available for nearly all kinds of microprocessors and computers. The capacity of the telephone circuits is limited to 1,200 bps and may be error prone at data rates greater than 300 bps. Therefore, this type of communication would not be suitable for routine exchange of large volumes of data, but would satisfy the requirements of data requests in phase 1.

Packet switched networks provide higher transmission rates than telephone lines. The former currently have connections to 36 countries, in particular to those of Western Europe, North America, Far East and Australia. These systems offer transmission lines up to 9,600 bps and would be suited to interactive applications as well as reliable transmission of long data files. Real-time transmission of seismic data from a three-component station would only require 2,400 bps, if a sampling frequency of 40 Hz (16 bit word length) is assumed.

Protocols for data handling are made available as part of software packages supplied by computer manufacturers. It would be necessary to agree upon a standard protocol before the system is used intensively for Level II data exchange on an international level.

The most advanced telecommunication technology is presently provided by satellites such as INTELSAT. The capacity of this system as described in US/GSE/16 (1981) allows transmission at a data rate as high as 90 Mbps. Compared to this, for all data of the NORESS array consisting of 25 seismic stations with a total of 36 seismometers (sampling rate 40 Hz), 32 kbps is sufficient. Real-time data transmission via INTELSAT from the NORESS array as well as from six RSTN stations in Canada and the United States of America to a data centre in Washington clearly demonstrates that satellite communication has opened a new dimension for a future seismic monitoring system. From the technical point of view it is no longer unrealistic to assume on-line transmission of seismic data from all stations of a global network to the IDCs, even if it consisted of 100 stations or more. Taking this possibility into account, we think that it would be absurd if, in the future, verification were primarily based on Level I data and did not make use of Level II data to the full extent provided by technology. This implies that other components of the system have also to be upgraded to an adequate technical level.

6. Gradual Improvements of Verification Capabilities

A monitoring system of 100 kt explosions marks only the first phase of a development aimed at world-wide verification of nuclear tests at the lowest significant yield level, which, at present, is regarded to be about 1 kt. This goal could be achieved by a gradual upgrading of the GSETT system. The improvements are related to different components that could be incorporated progressively defining different phases in the development of the verification system.

6.1 System performance in phase 2

As a first step in the process of system upgrading the inherent capabilities should be used to their full extent, operating the GSETT-system on an improved technical level. This could easily be achieved by the following means:

- implementation of efficient automatic detection algorithms at digital stations in order to lower single-station detection threshold. This would allow detection of seismic signals at a S/N ratio of about 1.5, which is considered to be the lower limit at which a seismic signal can clearly be distinguished from background noise;
- replacement of analog seismic stations by digital ones. As far as the technological design of these stations is concerned, standards for hardware and software components should be specified by the GSE. A possible technical concept for the stations was outlined in chapter 4;
- extend the network by including existing seismic stations in areas with insufficient network detection capability. According to Fig. 2 this holds especially for areas in Asia, South America, and Africa. As an alternative new stations could be deployed as well. For site selection, noise conditions should be taken as the main criterion. An average noise level of about 1 nm to 3 nm at 1 Hz is desirable.

6.1.1 Verification capabilities

In computing the detection capability in magnitude (mb) units for the seismic networks discussed in this paper, an amplitude correction up to 180 degree distance was applied. This is an extension of previous studies which restricted this correction to distances of less than 100 degrees. At this point we want to emphasize the importance of this amendment with regard to an improved detection capability for the southern hemisphere. It has been stated that in the southern hemisphere the detection capability is lower due to the small number of stations in this area. By extending the amplitude-distance corrections to 180 degrees, i.e. by including PKP phases, the detection capability in the southern hemisphere can be dramatically improved without installing new stations. This can be demonstrated by looking at a recording of an underground nuclear explosion at the French test site in the South Pacific. Fig. 10 shows 13 seismograms from the GRAEFENBERG (GRF) array in Southern Germany from which the uppermost seismogram is computed by the delay-and-sum method to improve S/N ratio. The GRF station A1 is located at a distance of 143.7 degrees from the epicentre and records a clear signal from this estimated 5 to 10 kt explosion. In the lower left corner of Fig. 10 the phase association and location given by the EIDC Stockholm, Sweden, is plotted. The event was defined on the basis of two PKP detections and only two P detections. Without the PKP phases this event would have remained undetected. It is important for the capability of the phase 2 system that data centres use the PKP phases on a routine basis.

Considering additional improvements in technical operation described above, the detection threshold of the GSETT network can easily be lowered by 0.3 magnitude units. From Fig. 4 we can then derive a world-wide detection capability of at least magnitude 4.7 (mb). In the model calculations this detection level can be achieved by lowering the S/N ratio necessary for signal detection to 1.5. This value seems to be realistic as soon as automatic detectors are implemented at the seismic stations.

Using again the magnitude-yield relation from equation (1b) the magnitude 4.7 (mb) detection threshold corresponds roughly to about 5 kt explosions in wet hard rock and to about 50 kt explosions in dry unconsolidated rock. Similarly it can be estimated that operational improvements will clearly increase the number of reportings of long-period signals. Narrow filter characteristics could lower the noise estimates at least by a factor of two. These estimates (Table 1) were guessed from poor reportings during the GSETT in a very conservative way. This would in turn lower the detection threshold in terms of surface-wave magnitude M_s from Fig. 7 by 0.3 units, resulting in a world-wide identification capability of at least magnitude 3.7 (M_s). Using the M_s -yield relation from equation (3) this means a verification level of about 50 kt for nuclear explosions.

6.1.2 System operation

Operation of the phase 2 system does not differ substantially from that of the extended test as far as extraction, transmission and compilation of Level I data are concerned. The number of parameters to be reported will not be increased significantly but will be based on the minimum set supplemented by a few long-period data used for routine determination of M_s magnitude. In this phase seismic events would first of all be identified on the basis of accurate hypocentre location,

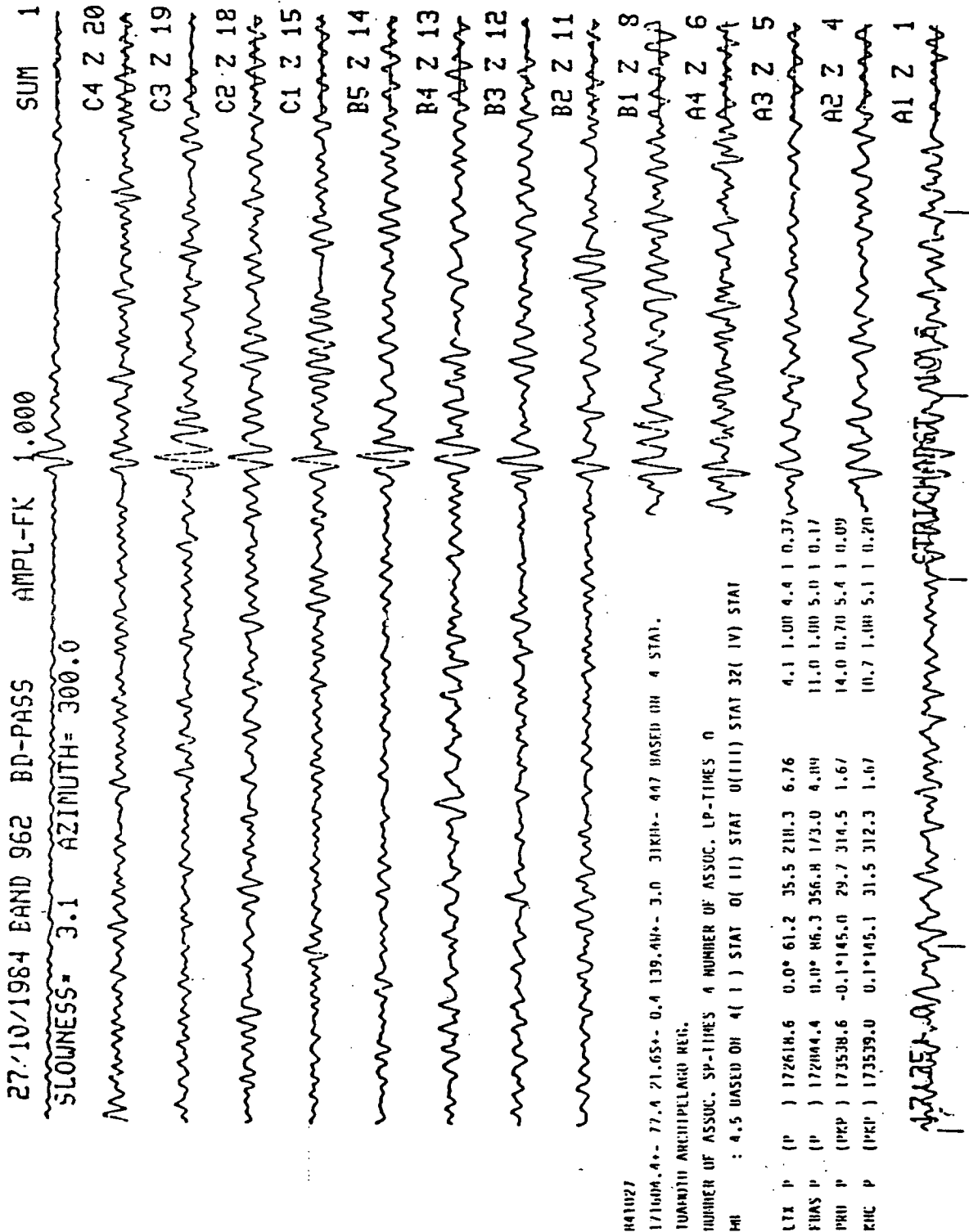


Fig. 10: French underground nuclear explosion (estimated yield 5 kt to 10 kt) recorded with GRAEFENBERG-array seismometers. Distance to test site is 143.7 degree.

first-motion sign as well as of Ms:mb ratio. These data would be used as a basic criterion for definition of suspicious events. In this case a final decision would require careful analysis of the original seismograms (Level II data) by national means. For this purpose Level I data are not considered to be adequate even if the complete parameter set were available.

At the end of phase 2, stations with digital equipment will dominate in the global network although some analog stations are still expected to be in operation. The technical level of digital stations will differ in so far as only a proportion of them will have access to telecommunication systems. Therefore Level II data exchange will mainly be based on computer tapes. It is estimated that the phase 2 system could be fully operational in about four years.

6.2 System performance in phase 3

Upgrading of the technical facilities of the seismic stations will be continued in this phase. Significant improvements of the system verification capability, however, are achieved by optimizing the distribution of seismic stations. The model of a network that is expected to allow world-wide detection of about 1 kt explosions in wet hard rock or about 10 kt explosions in dry porous media is shown in Fig. 11. Compared to the improved GSETT network of phase 2, this configuration of a total of 50 stations is characterized by a more homogeneous geographical distribution. It is a hypothetical network which is intended to be an updated version of Network III from a previous GSE report (CCD/558, 1978). It mainly consists of existing and planned seismic stations, which should be upgraded to satisfy the technical specifications defined in chapter 4. Table 2 shows the station co-ordinates. In addition, average noise values are set to the minimum requirements: namely 3 nm and 50 nm at 1 s and 20 s, respectively.

To achieve the system performance required in this phase, considerable effort should be made with regard to

- development and operation of new dedicated seismic stations in various countries of the globe;
- upgrading the equipment of all stations to the level of dedicated stations;
- connection of dedicated stations to telecommunication systems to provide real-time transmission of recorded seismic data (Level II data);
- operation of IDCs that take over the functions of control and receiving centres for the seismic stations and for continuously incoming Level II data as well.

6.2.1 Verification capabilities

Estimates of detection, location and identification thresholds were calculated for the hypothetical network in Fig. 11 following the same procedures as described in detail in chapter 3. Fig. 12 shows the 90 per cent probability in magnitude mb-units of detection at four or more stations with a S/N ratio of at least 1.5.

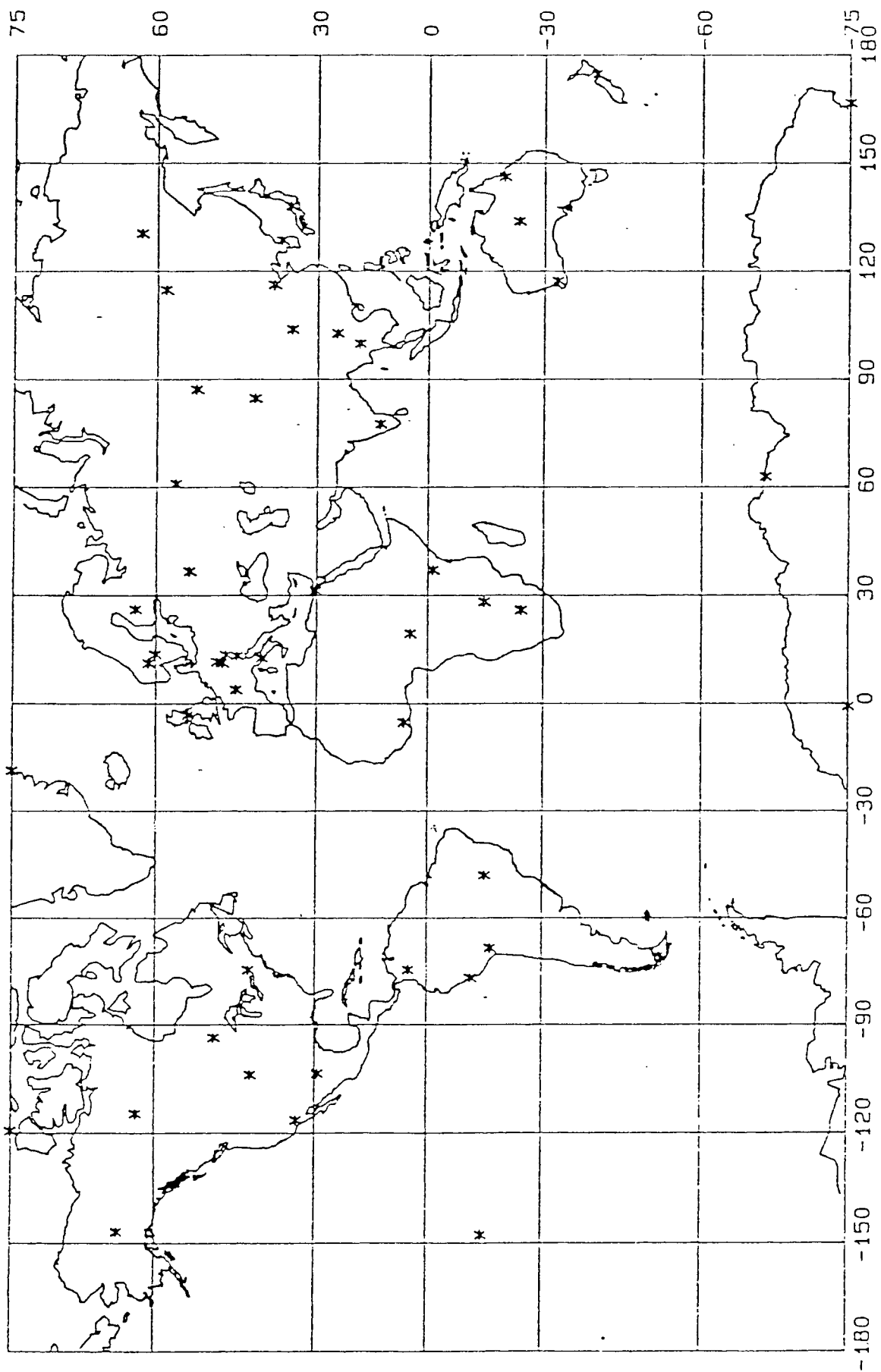


Fig. 11: 50 station level 3 network

Table 2: Station codes, coordinates and noise statistics
for level 3 network

i	station code	lat.	long.	SP-noise		LP-noise	
				ampl [nm]	sd [mb units]	ampl [nm]	sd [Ms units]
1	aspa	-23.67	133.90	3.00	0.20	50.00	0.30
2	bdf	-15.66	-47.90	3.00	0.20	50.00	0.30
3	bij	40.04	116.18	3.00	0.20	50.00	0.30
4	bng	5.14	19.49	3.00	0.20	50.00	0.30
5	boc	5.32	-74.55	3.00	0.20	50.00	0.30
6	bod	58.84	114.72	3.00	0.20	50.00	0.30
7	bot	-24.49	25.94	3.00	0.20	50.00	0.30
8	chg	19.33	99.91	3.00	0.20	50.00	0.30
9	ctao	-20.09	146.25	3.00	0.20	50.00	0.30
10	dag	76.77	-18.65	3.00	0.20	50.00	0.30
11	eka	55.33	-3.16	3.00	0.20	50.00	0.30
12	elt	54.17	87.16	3.00	0.20	50.00	0.30
13	fbas	64.77	-146.89	3.00	0.20	50.00	0.30
14	gba	13.60	77.44	3.00	0.20	50.00	0.30
15	grf	49.69	11.22	3.00	0.20	50.00	0.30
16	hfs	60.13	13.70	3.00	0.20	50.00	0.30
17	hlw	30.34	31.36	3.00	0.20	50.00	0.30
18	kba	47.08	13.34	3.00	0.20	50.00	0.30
19	khc	49.13	13.59	3.00	0.20	50.00	0.30
20	kic	6.86	-5.28	3.00	0.20	50.00	0.30
21	kmi	25.12	102.74	3.00	0.20	50.00	0.30
22	ksr	38.51	128.65	3.00	0.20	50.00	0.30
23	lac	34.39	-116.41	3.00	0.20	50.00	0.30
24	lor	47.27	3.85	3.00	0.20	50.00	0.30
25	lpb	-17.21	-68.53	3.00	0.20	50.00	0.30
26	lsz	-15.28	28.19	3.00	0.20	50.00	0.30
27	ltx	29.33	-103.67	3.00	0.20	50.00	0.30
28	lzh	36.09	103.84	3.00	0.20	50.00	0.30
29	mat	36.54	138.21	3.00	0.20	50.00	0.30
30	maw	67.60	62.87	3.00	0.20	50.00	0.30
31	mbc	76.24	-119.36	3.00	0.20	50.00	0.30
32	mns	42.39	12.68	3.00	0.20	50.00	0.30
33	mox	50.65	11.62	3.00	0.20	50.00	0.30
34	nai	-1.37	36.98	3.00	0.20	50.00	0.30
35	nb2	61.04	11.21	3.00	0.20	50.00	0.30
36	nna	-11.99	-76.84	3.00	0.20	50.00	0.30
37	nwao	-32.93	117.23	3.00	0.20	50.00	0.30
38	obn	55.12	36.60	3.00	0.20	50.00	0.30
39	pmo	-15.00	-147.90	3.00	0.20	50.00	0.30
40	rsny	44.55	-74.53	3.00	0.20	50.00	0.30
41	rson	50.86	-93.70	3.00	0.20	50.00	0.30
42	rssid	44.12	-104.01	3.00	0.20	50.00	0.30
43	sba	-77.85	166.76	3.00	0.20	50.00	0.30
44	spa	-89.76	-0.76	3.00	0.20	50.00	0.30
45	suf	62.72	26.15	3.00	0.20	50.00	0.30
46	sve	57.28	60.95	3.00	0.20	50.00	0.30
47	wel	-41.29	174.77	3.00	0.20	50.00	0.30
48	wmq	43.82	84.69	3.00	0.20	50.00	0.30
49	yak	62.10	130.55	3.00	0.20	50.00	0.30
50	yka	62.49	-114.61	3.00	0.20	50.00	0.30

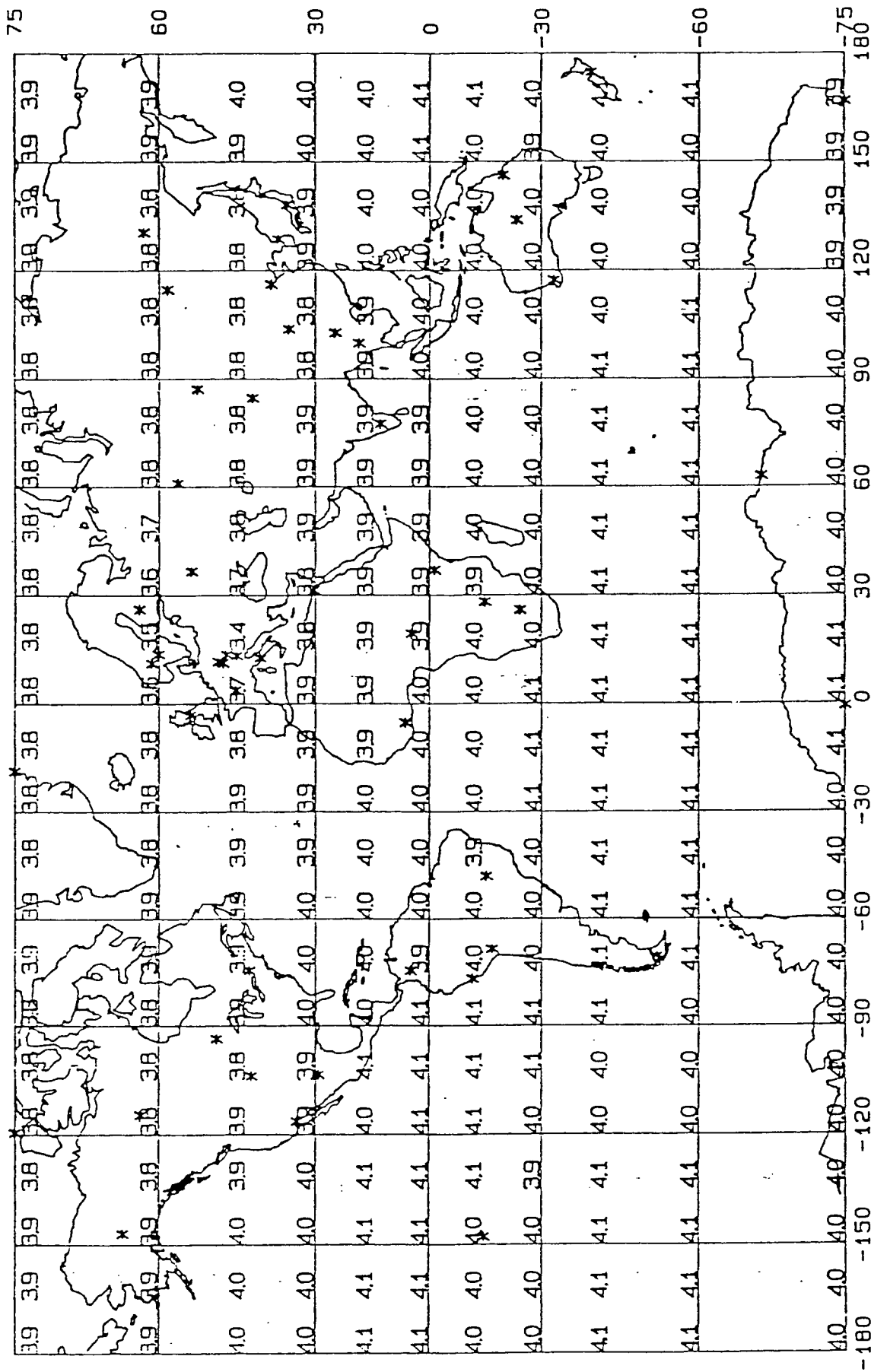


Fig. 12: 50 station level 3 network detection capability corresponding to a 90% probability (at 4 detecting stations or more) with a signal-to-noise ratio of at least 1.5 in terms of mb-units. Calculations of mb are based on amplitude-distance corrections from Fig. 3.

Calculations of mb are based on P and PKP waves with the amplitude-distance curve from Fig. 3. Although there is still a higher detection capability in the northern hemisphere, in particular in Western Europe and Scandinavia, the global variation of thresholds is much smaller than in Fig. 4. In most continental areas the detection threshold is lower than or equal to magnitude 4.0 (mb). Only in larger parts of the oceans, is it at a level of 4.1 (mb). It has to be emphasized that the fairly uniform detection capability is a result of the optimal global distribution of stations with identical noise characteristics. When phase 3 system comes into operation, lower detection thresholds should be possible because several stations will have lower noise values than the assumed minimum requirements.

It has already been mentioned that a magnitude value of 4.0 (mb) is equivalent to a yield in the order of 1 kt for explosions in wet hard rock (equation (1a)), or to a yield level of about 10 kt, taking into account muffling of signals by detonating explosions in dry unconsolidated sediments (equation (1b)).

Below 10 kt the possibility of efficient decoupling by detonating explosions in cavities has to be considered. The technique lowers the corresponding mb magnitude considerably. This can only be verified by regional (in-country) networks as will be described in chapter 7.

The estimated location capability for the phase 3 network (Fig. 11) is shown in Fig. 13. The numbers at the grid points give the location errors in kilometres at the detection threshold for a hypothetical explosion at that epicentre. The corresponding magnitude values are contained in Fig. 12. The location errors are in the order of 30 km to 60 km. Comparing these results with the location errors for the GSETT network at magnitude 4.0 (mb) (Fig. 6), a remarkable improvement due to better geographical station distribution can be concluded. We emphasize that this estimate has to be dealt with caution. More reliable and then often better location results can only be expected by using calibration events.

Finally we estimated the identification capability of phase 3 system based on the mb:Ms criterion. Fig. 14 gives a picture of the detection threshold in terms of surface-wave magnitude Ms units. The estimates are based on 0.9 probability of detection at two or more stations with a S/N ratio of at least 1.5. The "Prague" attenuation formula (2) was used as an amplitude distance correction.

In most parts of the northern hemisphere the values are below Ms = 3.0, especially on the continents. On the other hand there are large areas in the southern hemisphere where the detection threshold for surface waves is as high as 3.3 (Ms). Unless more stations are installed in the southern hemisphere this difference will always be the same.

Following the Ms-yield relation (3) a surface wave magnitude of 3.0 (Ms) corresponds to the yield of roughly 10 kt. As we used a rather optimistic noise value of 50 nm for all stations it can be concluded that a level of 10 kt is a lower limit for the application of mb:Ms identification criterion. For smaller events which are to be detected by phase 3 system as shown in Fig. 12, other identification criteria have to be used which are listed in section 3.4.

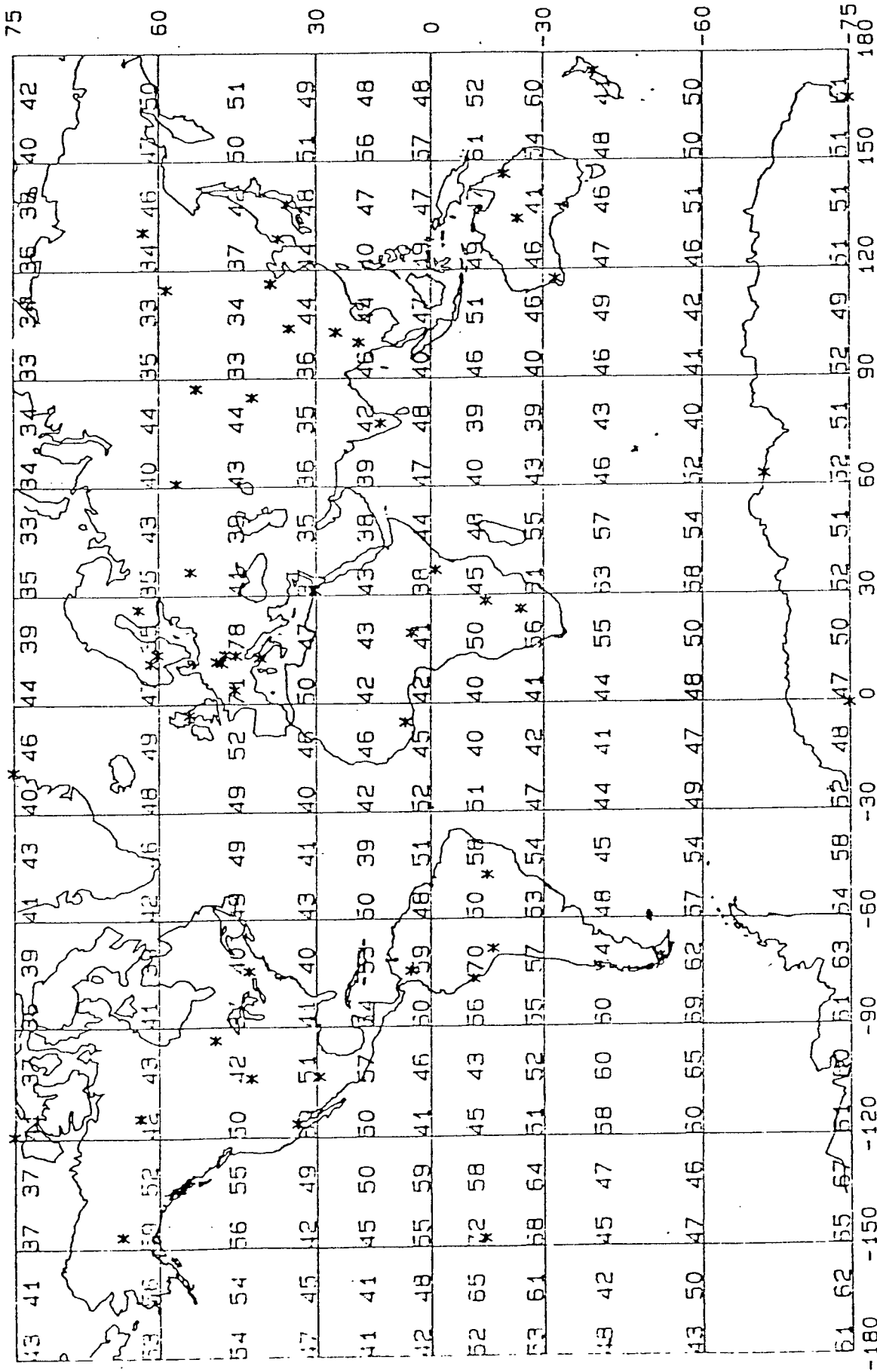


Fig. 13: 50 station level 3 network location capability at detection levels from Fig. 12.

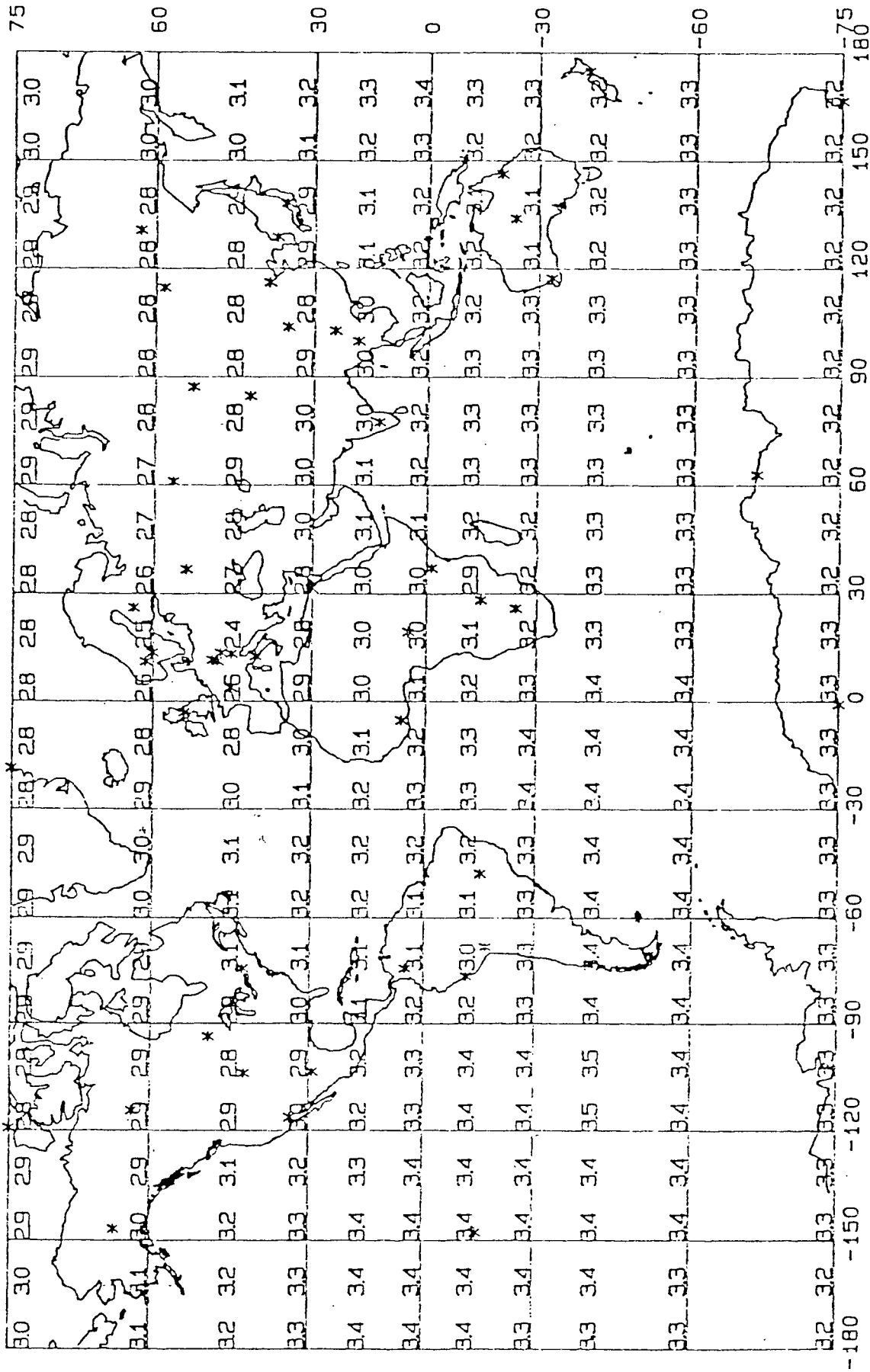


Fig. 14: 50 station level 3 network detection capability corresponding to a 90% probability (at 2 detecting stations or more) with a signal-to-noise ratio of at least 1.5 in terms of Ms-units. Calculations of Ms are based on amplitude-distance corrections from equation (2).

6.2.2 System operation

Due to the technical improvements in this phase some new aspects are introduced with regard to system operation.

Extraction and reporting of Level I data by national facilities would not be necessary any more as automatic trigger algorithms implemented at the stations would provide IDCs with the basic data for event definition. False alarms could easily be excluded by visual inspection of Level II data received from each station. Moreover IDCs would be able to search for arrivals which were missed by the detector of a station but were detected at neighbouring stations. By re-analysing seismic records the number of unassociated detections could be reduced considerably. This was also proved by Bergkvist *et al.* (1983) on the basis of a small-scale data exchange experiment during a two-week period in October 1980. During the GSETT about 60 per cent of the reported arrivals never became associated with any of the events defined by the EIDCs. This again provides strong evidence for the importance of Level II data with respect to event definition. Another essential point relates to the advantages of waveform data with respect to identification of seismic phases that provide higher accuracy of epicentre determination and depth estimation (Roy, 1982). Therefore, the elaboration of procedures for analysis of Level II data at IDCs is urgently needed.

Apart from processing of Level II data the functions of the IDCs remain unchanged. As far as changes of the technological equipment are concerned, improvements at IDCs would mainly involve computer capacity and data exchange via high speed telecommunication systems. Advanced technology in these fields would facilitate compilation of event bulletins, archiving and management of Level I data and Level II data, and communications with other IDCs as well as with national facilities of participating States.

In this phase immediate availability of Level II data from all seismic stations of the network at the IDCs would facilitate the process of data requests in order to identify suspicious events. At a magnitude level of 4.0 (mb) the number of events that will a priori not be classified as earthquakes and consequently declared to be suspicious is estimated to be at most 500 per year. This was estimated from the recurrence curve based on ISC data for shallow events (focal depth < 15 km) in 1982. Each country would have unhindered access to the Level II data archives. Exchange of Level II data at this stage would preferably be made via telecommunication channels on the basis of standard protocols elaborated by the GSE for different communication systems. Optionally, the data could also be provided on magnetic tape or, if requested, in any other form.

In essence, phase 3 system defines the technological and operational framework of a global seismic monitoring system for world-wide verification at a yield threshold of 1 kt to 10 kt explosions depending on source environments as explained in chapter 2.

7. Implementation of Regional Networks

An increase in verification capabilities beyond the level of magnitude 4.0 (mb) could be achieved on the regional level by installation of regional networks, in particular in the territory of nuclear weapon States. These stations monitor areas which have a high potential for carrying out clandestine nuclear tests. In principle, it is possible to lower the detection threshold to any

magnitude level by increasing the density of the seismic stations. The degree of adequate verification that has to be achieved is less of a technical problem than a political one. Therefore, location, configuration and operation of regional networks would be primarily the subject of arrangements among nuclear weapon States. These arrangements would also include specifications on test sites and calibration parameters. Data exchanged or collected among nuclear weapon States would be made available to non-nuclear weapon States, thus adding a desirable degree of redundancy to the verification system.

We will limit the following discussion to some seismological aspects of regional networks. Seismic stations in Western Europe and Scandinavia which participated in the GSETT can be regarded as an example of this type of network. The geographical distribution of 25 stations selected from the GSETT network shown earlier in Fig. 2 is plotted in Fig. 15 on a 2-degree grid. Using the station noise data from Table 1 and an attenuation curve for regional distances and shield type path (Der et al., 1982), the 90 per cent probability for detection at four or more stations with a S/N ratio of at least 1.5 is given in Fig. 16.

It can be seen that the regional detection capability of this subnetwork of 25 mostly high-quality stations is considerably higher than the average global estimate from Fig. 4, even if the differences in input parameters are taken into account.

For the territory of nuclear weapon States, Dahlman and Israelson (1980) calculated detection capabilities for models of 20 and 30 uniformly distributed stations in the United States of America and in the USSR assuming that, with a probability of 90 per cent, seismic signals are detected at four or more stations with a S/N ratio of 1.5. Estimates of detection threshold in terms of mb were given for P waves as well as for Lg waves on the basis of distance attenuation curves from Veith and Clawson (1972) and Nuttli (1973), respectively. According to the results obtained for the network of 20 stations in the United States of America the detection level turned out to be 3.6 (mb) for P waves and 2.3 (mb) for Lg waves. For a network of 20 stations in the USSR the corresponding magnitudes were 3.3 (mb) for P waves and 2.7 (mb) for Lg waves. The results for the P waves however were based on an amplitude-distance relation which was considered to be valid for shield areas in the USSR. It was also emphasized by the authors that the Lg results obtained for the two countries, in particular for the USSR, could well be too optimistic because of uncertainties in the Lg amplitude-distance curve.

The detection threshold of the USSR network obtained for P waves was found to be in reasonable agreement with estimates by Evernden (1976) who obtained values between 3.2 and 3.7 for a network composed of 15 internal and 15 external stations.

The results of model calculations, using only P waves, are certainly conservative estimates of the detection capability of networks containing in-country stations because regional phases like Lg waves can considerably enhance the detection capability. An estimate which made use of multiple regional seismic phases like Pn, Pg and Lg was given by Hannon (1983). The station distribution, was identical with the model used by Evernden (1976); however, Hannon located hypothetical seismic arrays at the sites of the 15 internal stations. With these modifications 90 per cent detection probability in the USSR

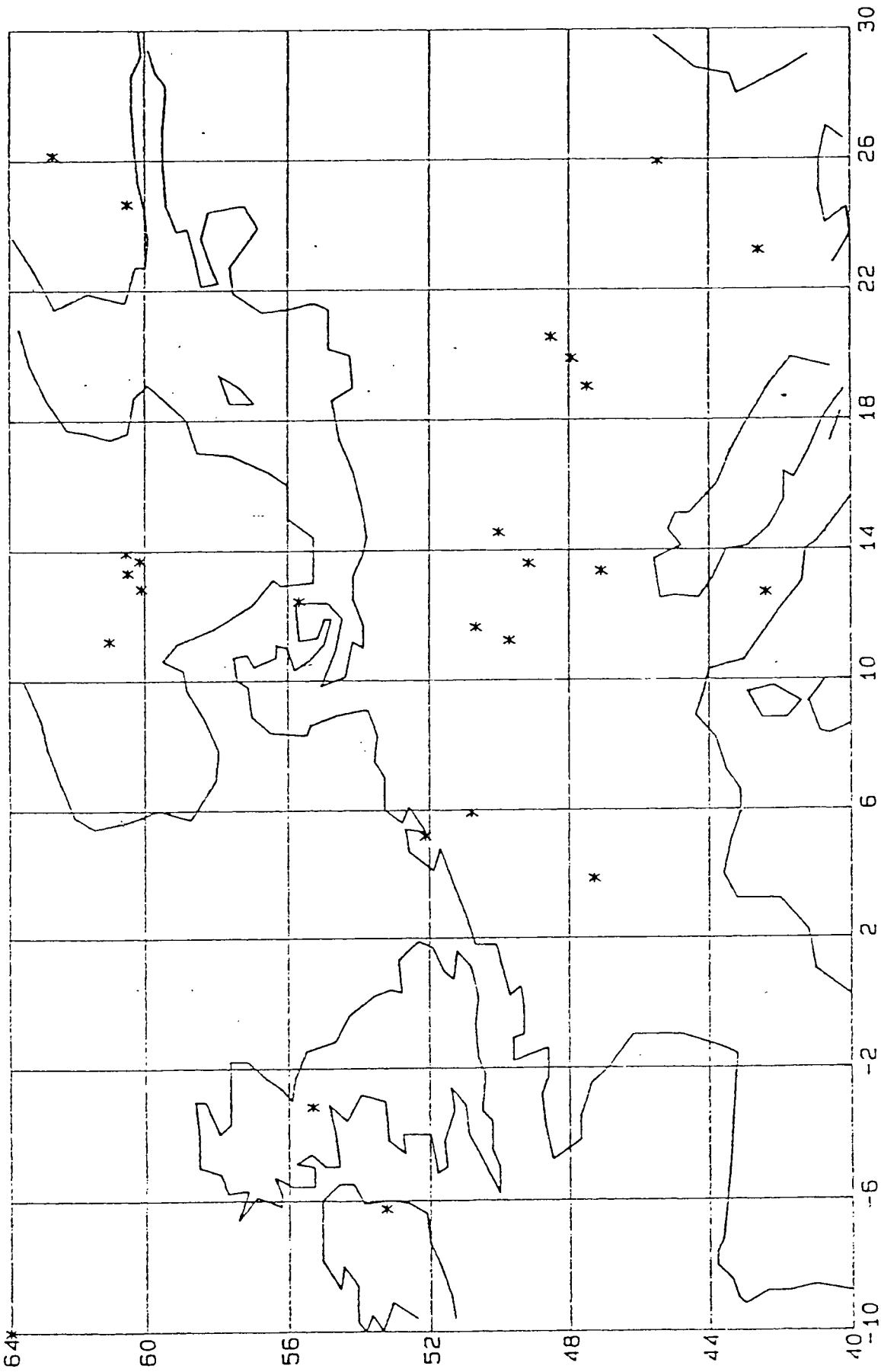


Fig. 15: 25 station regional EURONET

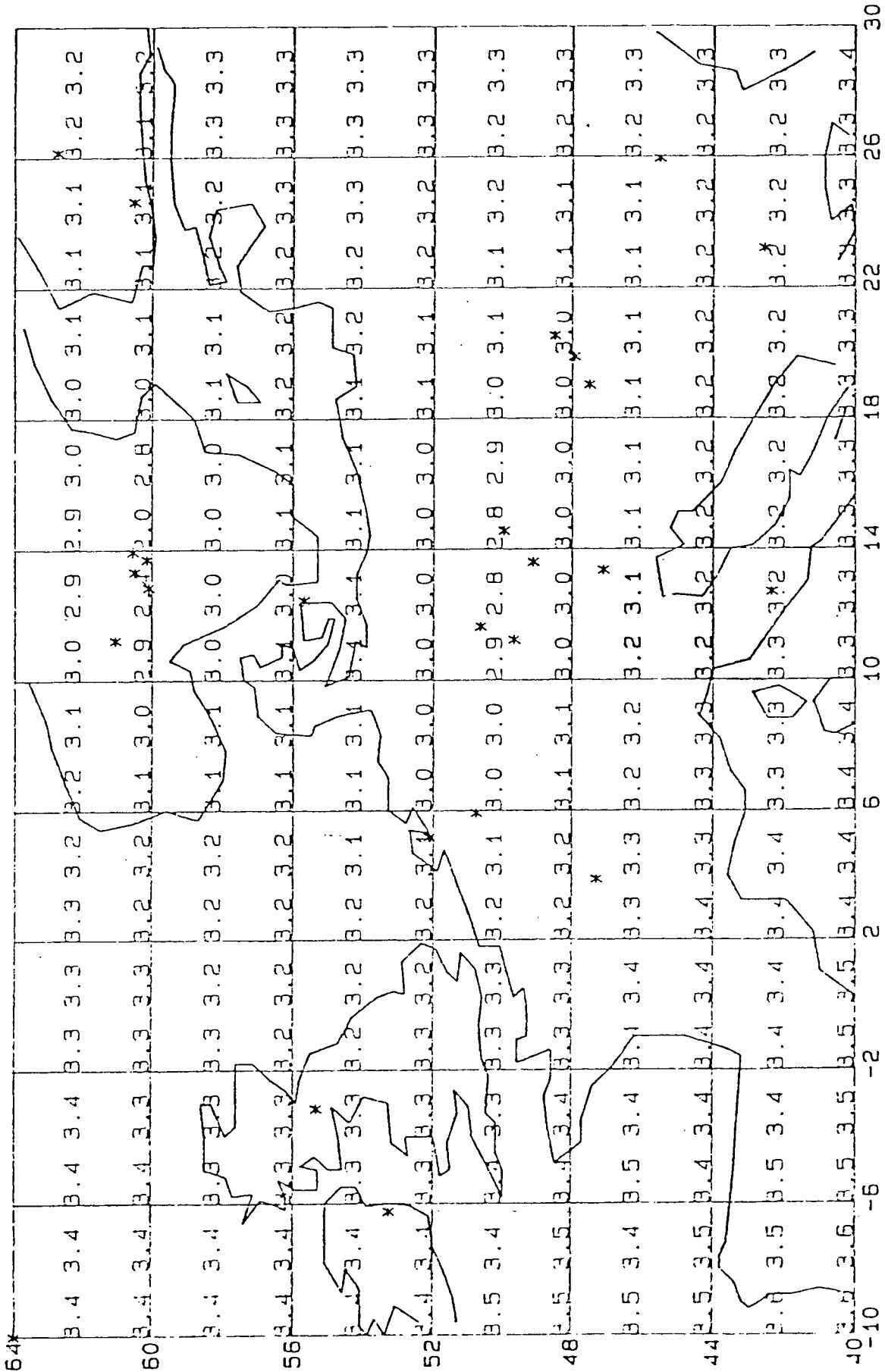


Fig. 16: 25 station EURONET regional detection capability corresponding to a 90% probability (at 4 detecting stations or more) with a signal-to-noise ratio of at least 1.5 in terms of mb-units. Calculations of mb are based on amplitude corrections from Fig. 3 for distances less than 25 degrees.

was estimated to be at 2.4 (mb) for areas of special interest and between 3.0 (mb) and 3.1 (mb) over about 90 per cent of the country. Obviously detection of seismic signals at this magnitude level could also be achieved inside the United States of America if a similar model for a regional seismic network were used.

Another method we used for estimating detection capability of regional networks is based on experimental data collected in Europe from long-range refraction studies. This approach does not involve the difficulties encountered with the various assumptions made with the model calculations, but gives a realistic estimate of the minimum station separation required for detection of signals from explosions of the order of 1 ton to 10 tons. These results are discussed in detail in part C.

As far as system operation is concerned, implementation of regional networks in a global seismic monitoring system to achieve reliable verification of evasion attempts down to the level of 1 kt would obviously require a much larger technical input with regard to

- number of seismic stations to be operated and maintained;
- volume of data to be transmitted;
- number of events to be processed.

Nevertheless, the principles of system operation as outlined for the phase 3 verification system in section 6.2.2 would not have to be changed. This also applies to the technical equipment of such an extended network that could comprise more than 200 stations including seismic arrays.

The performance requirements for a seismic verification system - and especially those for in-country stations - are established by political and military considerations. Seismologists provide the technical specifications of the seismic system necessary to meet those requirements.

Nuclear weapon States might look upon the in-country stations combined with their own national technical means as a verification system independent of the earlier described global network. As the global verification capability of the in-country stations is very limited, it is, however, essential that an international verification system of highest quality is available to all parties to a Nuclear Test Ban Treaty.

PART C: CAVITY DECOUPLING OF UNDERGROUND NUCLEAR EXPLOSIONS

1. Introduction

Clandestine underground testing of nuclear explosions is a serious threat to any treaty which partly or comprehensively bans nuclear weapon tests. Therefore, the verification measures of such a treaty have to be so effective that clandestine testing has only little chances to go undetected. This requires a good understanding of possible clandestine testing methods. Probably the most important method is decoupling the test device from the surrounding rock by detonating it at the centre of a sufficiently large cavity (Latter et al., 1961; Herbst et al., 1961, Murphey, 1961). This leads to reduced seismic wave radiation, compared with the radiation from a tamped explosion of the same yield.

We will concentrate in the following on a model of decoupling which is spherically symmetric, i.e. we assume that the explosive detonates at the centre of a spherical cavity. The radius of this cavity is the critical quantity. We will investigate theoretically how the displacement spectrum of the radiated P waves changes with increasing cavity size. The theory presented here is largely the same that has been used in earlier discussions of decoupling (Healy et al., 1971; Evernden et al., 1984).

In these discussions it is assumed that the pressure spectra of tamped and decoupled nuclear explosions have the same form, corresponding to a step-function pressure in the time domain. We investigate additionally what happens, if decoupling increases the high-frequency spectral pressure amplitudes relative to the low-frequency amplitudes.

A few numerical estimates will be given for displacement spectra and decoupling factors in the case of a 1 kt explosion in salt. The only decoupling experiment described in the open literature, the SALMON-STERLING experiment in the United States, took place in a salt dome and provided the information necessary for quantitative estimates of decoupling in salt (Springer et al., 1968; Sisemore et al., 1969; Healy et al., 1971).

Then we discuss the maximum distance to which a 1 kt decoupled explosion in salt can be observed. At frequencies up to 10 Hz such an explosion radiates seismic waves like a 5 t tamped explosion, according to a decoupling factor of 200. This is in the yield range of chemical explosions, as they are used in long-range refraction studies of the lower lithosphere. From long-range profiles with underwater, quarry-blast and borehole-explosion excitation of seismic waves, as observed mainly in Europe over the past 20 years, a maximum distance of the Pn wave of about 500 km for a 1 kt decoupled explosion is derived. This new estimate bears on the density of station-networks inside the United States of America and the USSR, which are necessary for monitoring a comprehensive test ban or a threshold test ban with low yield threshold.

Finally, we briefly discuss the possibility to exploit the relatively weak decoupling at higher frequencies than 10 Hz, say at 30 Hz, for monitoring decoupling attempts.

2. Source Model of a Nuclear Explosion

For seismological purposes, a nuclear explosion (tamped, partially decoupled or completely decoupled) is fully described by the pressure function $p(t)$ at the elastic radius r_{el} . Given these two quantities, the radiation of seismic waves both through a homogeneous medium and through a realistic earth structure can readily be calculated. For the discussion of decoupling it is sufficient to consider a homogeneous medium with observation points in the far-field, i.e. at least several wavelengths away from the explosion. In this case the spectrum of the P-wave far-field displacement follows from the theory developed by Sharpe (1942):

$$U(\omega) = \frac{0.75 r_{el}^3}{\rho V r} \cdot \frac{i \omega P(\omega)}{v^2 - 0.75 r_{el}^2 \omega^2 + i V r_{el} \omega} \quad (1)$$

where

ω = angular frequency,

$P(\omega)$ = spectrum of the pressure $p(t)$,

V = P-wave velocity,

ρ = density,

r = distance to observation point,

i = imaginary unit.

Eq. (1) is valid for a Poisson solid, i.e. a medium whose P-wave velocity is $\sqrt{3}$ times the S-wave velocity. This is a reasonable assumption for many rocks, and it is sufficient for a discussion of decoupling. For a given rock type in which nuclear tests are made V and ρ are fixed, and the spectrum (1) depends only on the value of the elastic radius r_{el} and on the pressure spectrum $P(\omega)$.

The pressure time function and spectrum can be written in a different form, which is more suitable for later discussions:

$$\left. \begin{aligned} p(t) &= P_0 f(t) \\ P(\omega) &= P_0 F(\omega), \end{aligned} \right\} \quad (2)$$

where P_0 is the peak pressure and $f(t)$ the normalized pressure function whose maximum value is 1. $F(\omega)$ is the spectrum of $f(t)$. Then (1) reads

$$U(\omega) = \frac{0.75 r_{el}^3 P_0}{\rho V r} \cdot \frac{i \omega F(\omega)}{v^2 - 0.75 r_{el}^2 \omega^2 + i V r_{el} \omega} \quad (3)$$

The peak pressure P_0 is the maximum pressure, under which the rock reacts according to the laws of linear elasticity; it is a material property. The elastic radius r_{el} depends also on the rock type and in addition on the yield W of the explosion and the degree of decoupling. The normalized pressure function $F(t)$ is, in the most general case, the sum of a step function and an impulsive term such as an exponential function,

$$f(t) = \delta H(t) + (1 - \delta)e^{-t/\tau}, \quad 0 \leq \delta \leq 1, \quad (4)$$

with the decay time τ . The spectrum of this function is

$$F(\omega) = \frac{\delta}{i\omega} + \frac{1 - \delta}{i\omega + 1/\tau} \quad (5)$$

The step-function term in (4) is thought to represent the static overpressure of hot gas which fills the explosion cavity after the detonation; the cavity is shot-produced in the case of a tamped explosion or pre-existing in the case of a decoupled explosion. The impulsive term in (4) is thought to be due to the shock wave produced by the explosion.

The law (4) covers most of the source-time functions that have been assumed for nuclear explosions. Considerable uncertainty exists with respect to the parameters of this law. Both pure step functions ($\delta=1$) and pure impulsive functions ($\delta=0$) have been proposed, sometimes for the same explosion. Thus, there is more uncertainty about source-time functions of nuclear explosions than about source-time functions of earthquakes, whose dislocation-time functions are close to step functions. For a more extended discussion of this uncertainty see Müller (1973) and Aki et al. (1974). Detailed and reliable investigations of explosion source-time functions have been made for low yields and were based on close-in measurements of displacements, particle velocities and accelerations in boreholes around a few explosions (Werth and Herbst, 1963; Rogers, 1966; Healy et al., 1971). These authors favour step-function pressure laws at the elastic radius, i.e. $\delta = 1$ in (4) and (5). Most discussions of decoupling are based on this form of the pressure, both for tamped and decoupled explosions, but below we will be more general.

3. Decoupling of Far-Field Spectra

Decoupling of a nuclear explosion depends on the radius r_c of the (spherical) cavity in which the explosion is detonated. A tamped explosion corresponds to $r_c \approx 0$, i.e. full coupling of the explosion to the rock; let the corresponding value of the elastic radius r_{el} , for a given yield W , be a . If then r_c is increased, coupling is decreased, and r_{el} decreases because the elastic limit of the rock is reached at shorter distances. The situation, in which $r_{el} = r_c$ and hence the rock acts linearly everywhere outside the cavity, is the beginning of full decoupling; let the corresponding cavity radius be a' : $r_{el} = a'$ at the beginning of full decoupling. If r_c is further increased, r_{el} increases again since then $r_{el} = r_c$. Decoupling increases further, although only at high frequencies as shown below.

We then compare the spectrum (3) for a tamped explosion ($r_c = 0$, $r_{el} = a$),

$$U(\omega) = \frac{0.75a^3 P_0}{\rho V r} \cdot \frac{1}{v^2 - 0.75a^2 \omega^2 + i v a \omega} \cdot \frac{\delta + i \omega \tau}{1 + i \omega \tau}, \quad (6)$$

next for the limiting case of a fully decoupled explosion ($r_c = r_{el} = a'$),

$$U'(\omega) = \frac{0.75a'^3 P'_0}{\rho V r} \cdot \frac{1}{v^2 - 0.75a'^2 \omega^2 + i v a' \omega} \cdot \frac{\delta' + i \omega \tau'}{1 + i \omega \tau'} \quad (7)$$

and finally for the general case of a fully decoupled explosion ($r_c = r_{el} > a'$),

$$U''(\omega) = \frac{0.75r_c^3 P''_0}{\rho V r} \cdot \frac{1}{v^2 - 0.75r_c^2 \omega^2 + i v r_c \omega} \cdot \frac{\delta'' + i \omega \tau''}{1 + i \omega \tau''} \quad (8)$$

In each of the three cases a spectrum of the normalized pressure of the form (5) has been assumed. The corresponding third factor in (6), (7) and (8) is an all-pass factor, if δ , δ' , or δ'' is close to 1, but it can develop into a more pronounced high-pass factor, if this parameter is much less than 1.

The yield dependence of the elastic radius a in (6) is usually assumed according to a cube-root law:

$$a = \epsilon W^{1/3} \quad (9)$$

For example, the tamped 5.3 kt explosion SALMON in salt had an elastic radius of 169 m (Healy *et al.*, 1971), resulting in $\epsilon = 97 \text{ m/kt}^{1/3}$.

The yield dependence of the radius a' in (7) follows from an expression of Latter *et al.* (1961), relating the static pressure in the cavity (here $\delta' P'_0$) to the energy E of the explosion and to the cavity volume:

$$\delta' P'_0 = (\gamma - 1) \frac{E}{\frac{4\pi}{3} a'^3} \quad (10)$$

where $\gamma = 1.2$ for an air-filled cavity and $E = 4.2 \cdot 10^{19} W$ with W in kt and E in erg. From (10) we have:

$$a' = \left(\frac{0.3E}{2\pi \delta' P'_0} \right)^{1/3} \quad (11)$$

The yield dependence of P_0'' in (8) follows from an equation similar to (10):

$$P_0'' = \frac{0.3E}{2\pi\delta''r_c^3} \quad (12)$$

The formulas (6) to (12) allow quantitative estimates of displacement spectra, provided that reasonable assumptions on the parameters (δ, τ) , (δ', τ') and (δ'', τ'') can be made.

From the spectra $U(\omega)$, $U'(\omega)$, $U''(\omega)$, given above, decoupling factors $D(\omega)$ can be defined as the ratio of the spectrum $U(\omega)$ of the tamped explosion and the spectrum of the decoupled explosion. Usually the limiting case of full decoupling is considered, which gives minimum values of the decoupling factor at full decoupling:

$$D(\omega) = \frac{U(\omega)}{U'(\omega)} \quad (13)$$

with $U(\omega)$ from (6) and $U'(\omega)$ from (7).

Two examples of displacement spectra and the decoupling factor are shown in Figs. 1 and 2. They correspond to the case of a 1 kt explosion in salt. The relevant parameters have been taken from the SALMON-STERLING decoupling experiment in which the 5.3 kt explosion SALMON produced a cavity with radius 17.4 m where later the 0.38 kt explosion STERLING was detonated (Healy et al., 1971). The P-wave velocity in salt is assumed to be $V = 4.7$ km/s. Three different cavity radii were chosen: (a) $r_c = 0$ (tamped explosion), the elastic radius being $r_{el} = a$ from (9); (b) $r_c = r_{el} = a'$ (limiting case of full decoupling) with a' following from (11) and depending on the static pressure P_0' ; (c) $r_c = r_{el} > a'$ (general case of full decoupling) with the corresponding static pressure P_0'' following from (12). The pressure-time functions at the elastic radius, assumed in Figs. 1 and 2, are all step functions. This is the usual assumption in discussions of decoupling, and, as far as the tamped explosion is concerned, it has an experimental basis from close-in observations of several explosions, as mentioned earlier. In the case of the decoupled explosion the assumption implies that the impulsive part of the pressure which certainly exists can be disregarded for seismic radiation.

All spectra shown in Figs. 1 and 2 have a well-defined low-frequency plateau, corner frequency and high-frequency slope corresponding to ω^{-2} dependence. Decoupling from $r_c = 0$ to $r_c = a'$ (=16.5 m in Fig.1 and 29 m in Fig.2) lowers strongly the low-frequency plateau, but at the same time shifts the corner frequency to higher frequencies. Thus decoupling at higher frequencies is much less than at low frequencies. Increasing r_c beyond a' then leaves the spectral plateau almost unchanged, but reduces the corner frequency such that now also high-frequency decoupling becomes large.

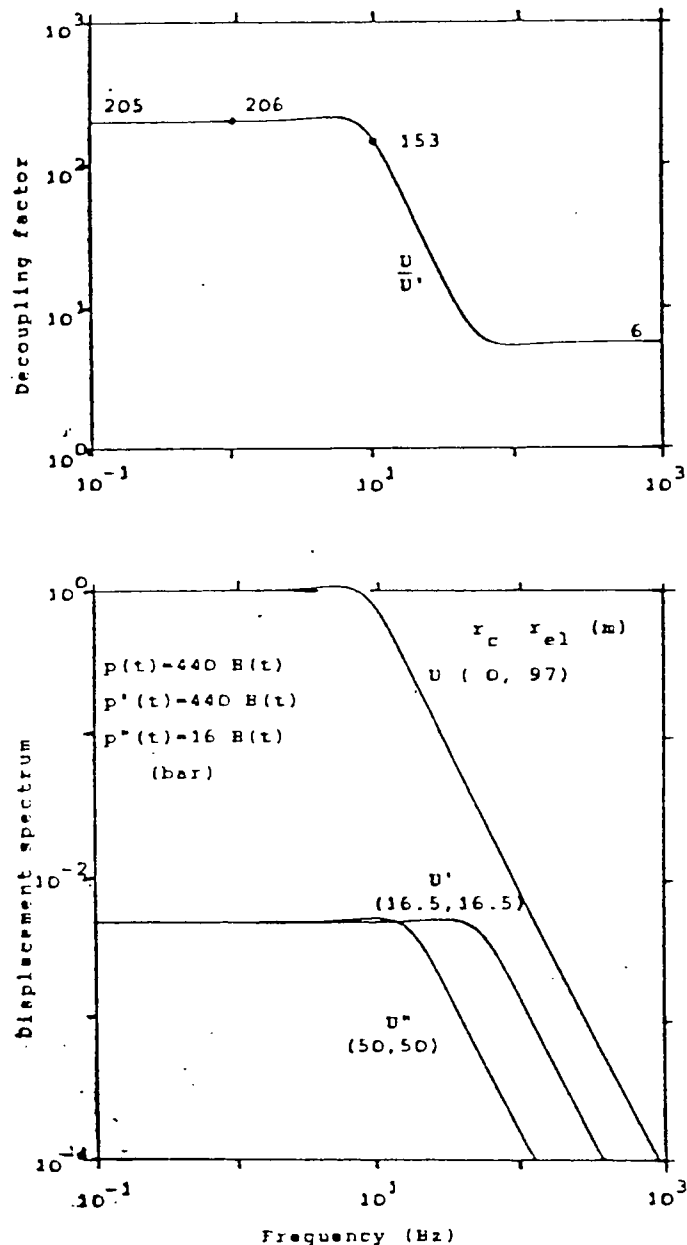


Fig. 1

Decoupling for a 1 kt explosion in salt under the assumptions, that (1) cavity formation does not lower the peak pressure under which the salt behaves linearly ($P_0 = P'_0 = 440$ bar (Healy et al., 1971)), and (2) the pressure at the elastic radius r_{el} is a step function in time; r_c is the cavity radius. Bottom: U is the far-field displacement spectrum of a tamped explosion ($r_c = 0$), U' the spectrum in the limiting case of full decoupling ($r_c = a' = 16.5$ m), and U'' the spectrum in the general case of full decoupling (under the assumption $r_c = 50$ m). The spectra are normalized with respect to the plateau of U . The corresponding pressure functions are $p(t)$, $p'(t)$ and $p''(t)$. Top: The decoupling factor shown is the ratio U/U' , corresponding to the limiting case of full decoupling. Decoupling is strong with values around 200 at frequencies up to about 10 Hz, then it decreases strongly to a value of 6 at about 60 Hz; the value is 206 at 1 Hz and 153 at 10 Hz. If $r_c > a'$, the decoupling factor U/U'' would be the same as U/U' at frequencies up to 10 Hz, but it would increase at higher frequencies, because U'' is lowered.

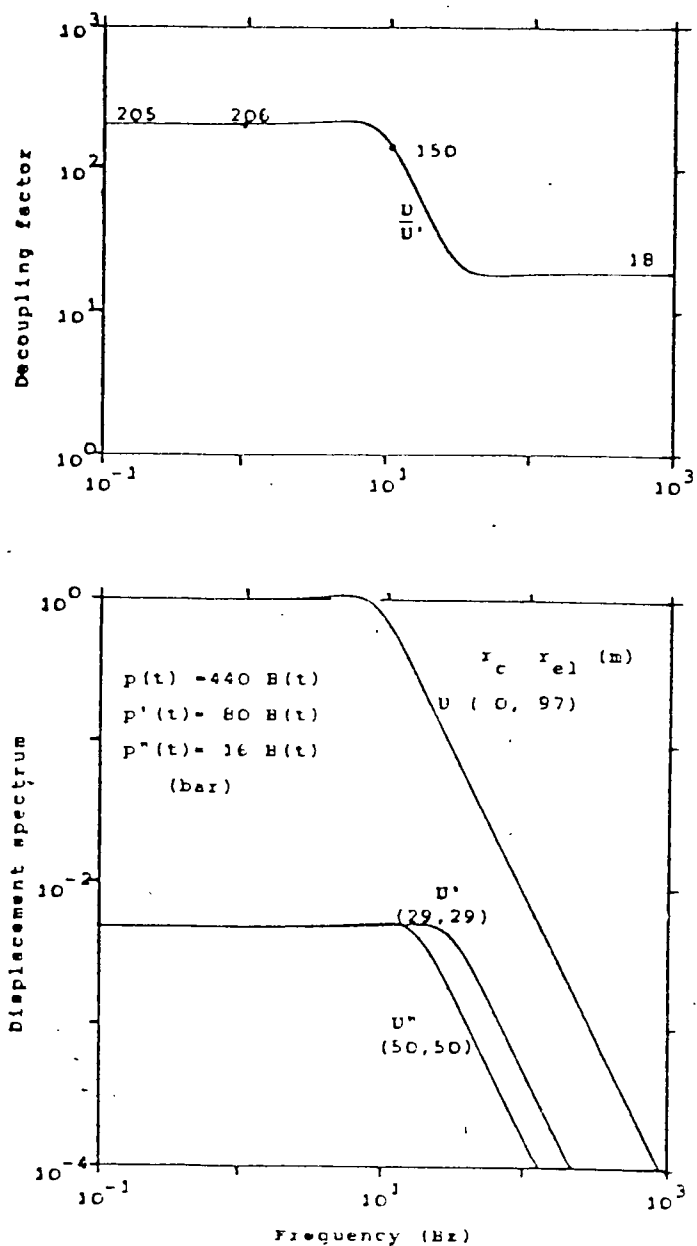


Fig. 2

The same as Fig. 1, but under the assumption that cavity formation for decoupling by a preceding explosion has weakened the salt and lowered the pressure, under which the salt behaves linearly, from $P' = P_0 = 440$ bar to $P' = 80$ bar (Healy et al., 1971). The main difference to Fig. 1 is that full decoupling now requires cavity radii $r_c \geq a' = 29$ m. High-frequency decoupling is increased.

In Fig. 1 the assumption was made that the peak pressure, under which the salt behaves linearly, is the same for the tamped and the decoupled explosion, i.e. that $P_0 = P'_0$ (= 440 bar). This is correct, if the process of cavity formation for decoupling does not weaken the salt. If the cavity is produced by a nuclear explosion, as in the case of the SALMON-STERLING experiment, the rock directly behind the cavity wall will probably be weakened with the effect that the peak pressure P'_0 is less than P_0 . Interpretation of the STERLING close-in observations gave $P'_0 = 80$ bar (Healy *et al.*, 1971) and thus a substantial reduction. The corresponding change in Fig. 2 is a shift to lower frequencies of the spectrum $U'(\omega)$. Moreover, this spectrum now corresponds to a cavity radius $a' = 29$ m. High-frequency decoupling is somewhat larger than in Fig. 1, but the essential effect of diminished values of P'_0 , relative to P_0 ; is that full decoupling requires now a cavity volume which is larger by a factor of P_0/P'_0 (in the present example 5.5).

The yield dependence of decoupling follows from (6) and (7) under the assumption of step-function pressures ($\delta = \delta' = 1$): the low and high-frequency values of the decoupling factor are independent of yield, but the transition between the two levels shifts to lower frequencies for increasing yield.

The low-frequency value of the decoupling factor, $D(0)$, has a simple meaning: in the frequency range where it applies, a decoupled explosion of yield W radiates seismic waves like a tamped explosion of yield $W/D(0)$. For a 1 kt explosion in salt this frequency range is below 10 Hz. Hence, at these frequencies a decoupled 1 kt explosion looks like a tamped 5 t explosion. This equivalence will be used later.

4. Impulsive Pressure Functions for Decoupled Explosions

In this section we briefly discuss far-field displacement spectra of decoupled explosions which correspond to more impulsive pressure functions at the elastic radius than the step functions assumed so far. It is clear that the pressure at the cavity wall has an impulsive component containing high frequencies (Latter *et al.*, 1961). In the case of only partial decoupling the elastic radius is larger than the cavity radius, and the high frequencies of the shock wave are lost on the way to the elastic radius. For example, the STERLING explosion was partially decoupled, with an elastic radius of 31 m as compared to the cavity radius of 17.4 m, and the close-in observation of this explosion could be explained by a pressure step at the elastic radius (Healy *et al.*, 1971). It is not clear, whether this situation continues to be applicable, if full decoupling is achieved. Full-decoupling experiments with nuclear explosions are the only means to decide this question; however, to our knowledge no such experiments have been described. Therefore, we give here a theoretical estimate of decoupling for a case which is substantially different from the usually assumed case of a step-function pressure at the cavity wall.

We assume that the normalized pressure of the fully decoupled explosion (limiting case) is

$$f'(t) = 0.1 H(t) + 0.9e^{-t/\tau'} \quad , \quad (14)$$

i.e. that the peak pressure is 10 times the static pressure ($b = 0.1$). Moreover, we assume $\tau' = 0.01$ s which is a rough estimate, based on scaling relations for tamped explosions (Mueller and Murphy, 1971). Both assumptions, on δ' and on τ' , could well be extreme cases, the reality being less extreme, i.e. $\delta' > 0.1$ and $\tau' < 0.01$ s. Decoupling results are shown in Figs. 3 and 4.

The spectrum U' of the decoupled explosion is now considerably richer in frequencies above 1 Hz, compared with the step-function pressure cases of Figs. 1 and 2. U' has a pronounced peak at about 20 Hz, and the decoupling factor is considerably reduced around 10 Hz, compared with the decoupling factors of Figs. 1 and 2. The minimum cavity radius for full decoupling is more than doubled, $a' = 35.4$ m in Fig. 3 and $a' = 62.5$ m in Fig. 4, compared with $a' = 16.5$ m in Fig. 1 and $a' = 29$ m in Fig. 2.

In summary, if for full decoupling the seismically active pressure at the cavity wall has a strong impulsive part, decoupling is technically more difficult to achieve and at the same time less pronounced than in the case where only a step-function pressure is operative. Theoretical estimates of decoupling under the step-function pressure assumption (Figs. 1 and 2) may give a too optimistic picture of the possibilities of decoupling, the assumptions behind Figs. 3 and 4, on the other hand, may be too pessimistic.

5. Discussion

5.1 Cavity size

Cavity sizes for full decoupling of 1 kt explosions in salt vary significantly, depending on the strength of the salt and the spectral content of the seismically active pressure at the cavity wall, the values found here ranging from 16.5 to 62.5 m. The corresponding variation in cavity volume is 1:55. Similar results can be expected for granite; other rocks such as alluvium or tuff appear less suited for cavity decoupling because of their lower strength.

The simplest method to produce cavities for decoupled tests is by other nuclear tests; this appears also to be the only way to make available a large enough number of cavities for test series of military significance. This way of producing cavities may, however, weaken the cavity wall and lower the maximum pressure with linear behaviour of the rock. As a consequence, larger cavities may be needed than in cases where they are produced by other means.

A more consuming method of cavity production is solution mining in salt, i.e. the salt is solved in water which is pumped away. Because the cavity walls are not weakened, probably larger yields can be decoupled than in cavities produced by nuclear tests. The technique of solution mining is used for the production of underground oil and gas reservoirs, and stable cavities with volumes of typically 10^6 m³ have been constructed. This volume value would correspond to a radius of 62 m under the assumption of a spherical cavity; stability considerations suggest shapes which are more elongated in the vertical direction. Formula (11) can be used to estimate roughly the maximum yield which can be coupled fully in such a cavity. Using $a' = 62$ m, $\delta' = 1$, $P_0 = 440$ bar, one obtains $W = 52$ kt.

We conclude that techniques are available to set cavity decoupling in effect over a relatively large yield range. This does not mean that they actually will be applied, since other factors, such as cost, long-time stability, radioactive fallout problems and the risk that clandestine tests are detected, will play an important role.

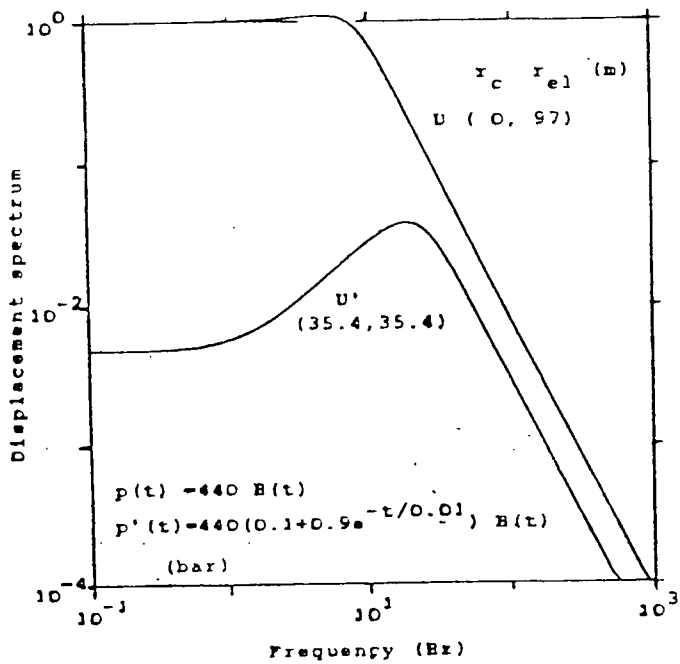
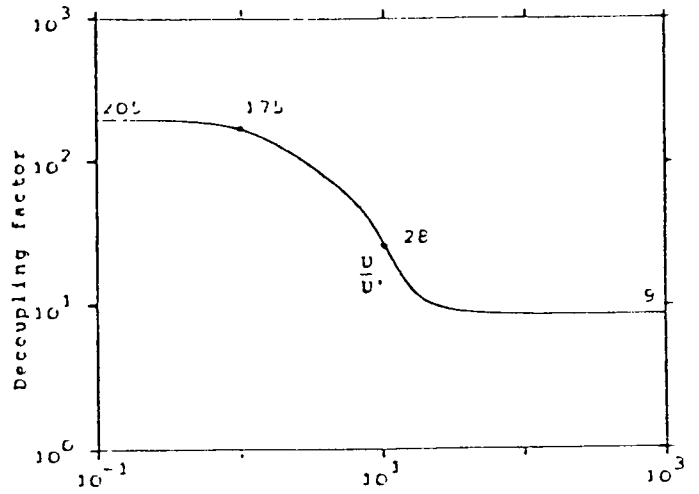
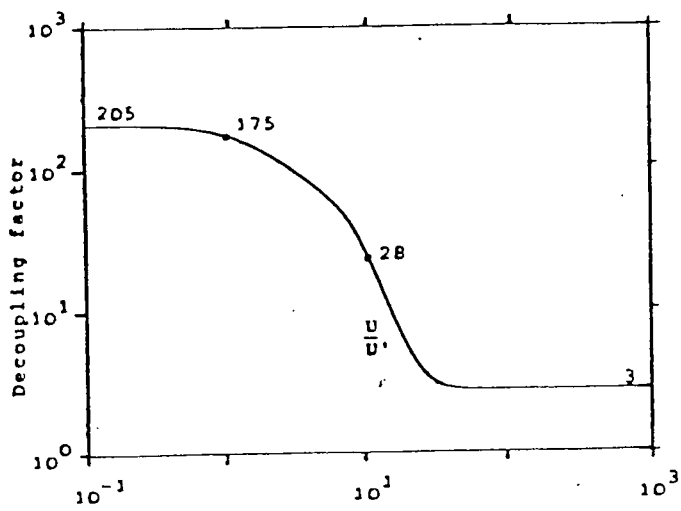


Fig. 3

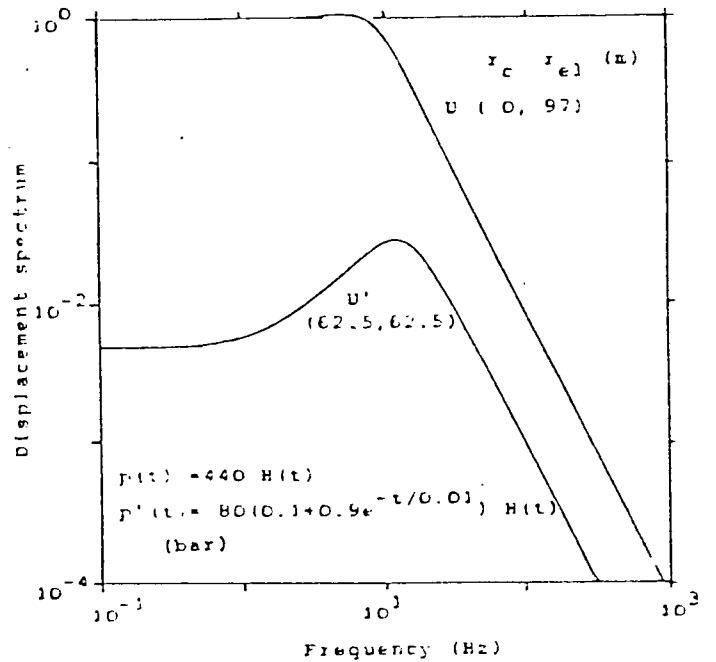


Fig. 4

Fig. 3

Displacement spectra and decoupling factor for a more impulsive pressure function $p'(t)$ than in Fig. 1. The spectrum U' is now strongly peaked at 20 Hz, and the decoupling factor is reduced accordingly. The minimum cavity radius for full decoupling is 35.4 m.

Fig. 4

The same as Fig. 3, but for a maximum pressure $p'(t)$ of 80 bar. Compare with Fig. 2, where the same peak pressure is assumed, but $p'(t)$ is a step function. The minimum cavity radius for full decoupling is 62.5 m.

5.2 Detection range of Pn

An estimate of the maximum distance to which a 1 kt decoupled explosion can be detected seismically follows from a comparison with experience from long-range refraction seismology. Here, chemical explosions in quarries, boreholes, lakes or offshore at sea are used and the Pn wave travelling in the lower lithosphere at depths to about 100 km is the main wave type studied; for a review see Fuchs and Vinnik (1982) and Prodehl (1984). Crustal phases such as Pg and Lg have rarely or never been investigated on long-range profiles in the relevant distance range, 300-1,000 km. Therefore, they are disregarded in the present investigation, although they certainly are also useful for detection purposes. Our question is then: to what distance would Pn be observable for a 1 kt decoupled explosion in salt? In the frequency range of long-range refraction seismology, 1-10 Hz, this explosion would be equivalent to a tamped 5 t explosion in salt, under the assumption of a decoupling factor of 200, as already mentioned (Figs. 1 and 2). Lower values of the decoupling factor (Figs. 3 and 4) would increase the equivalent yield of a tamped explosion accordingly, but to be on the safe side we assume the yield 5 t in the following. We then replace the 5 t nuclear explosion by a chemical 5 t explosion. Certainly, this is justified for the present purpose of an estimate, since both explosions release the same energy, although possibly according to somewhat different time functions. In this way we can now make use of the experience that has accumulated over the years in long-range refraction studies. In the following we concentrate (with one exception) on long-range profiles in Central and Western Europe; Fig. 5 shows a map with these profiles. The tectonic setting along them ranges from orogenically active on the Alpine long-range profile to rather stable on the profiles crossing Great Britain and France, respectively.

Yields of 1-5 t are quite typical values for excitation of waves by underwater explosions. Pn in such experiments is usually observed with good signal-to-noise (S/N) ratio to distances from 600 to 1,500 km. For instance, in the Early-Rise experiment in North America 5 t shots were detonated in Lake Superior and observed on several profiles with lengths up to 2,000 km (Warren et al., 1968; Ansorge, 1975). Depending on the profile, Pn was observed with good S/N ratio out to distances from 700 to 1,400 km. A second example is a long-range profile crossing France from Bretagne to Provence (Hirn et al., 1973). The shot sizes were 1-3 t, fired underwater off the coast of Bretagne, and Pn was observed with good S/N ratio out to 900 km. The third example are long-range profiles crossing Great Britain (Bamford et al., 1976; Faber, 1978). Fig. 6 shows record sections from these profiles. As indicated in the figure, the charge size for the most distant profile segments was 1.2 and 1.6 t, respectively. The record sections show quite variable S/N ratio for Pn, but even in the worst case (profile S2) Pn is detectable out to 700 km.

The objection may be raised here that underwater shots may couple seismic energy more efficiently into the ground than tamped explosions in solid rock. This is possibly true. We therefore go to the other limit and show in Figs. 7-10 record sections based on recordings of quarry blasts and borehole explosions. Quarry blasts close to the surface in fissured and fractured rock are certainly less efficient in producing seismic waves than tamped explosions far away from the surface in competent rock. The same is true for borehole explosions, in particular if they are above the water table.

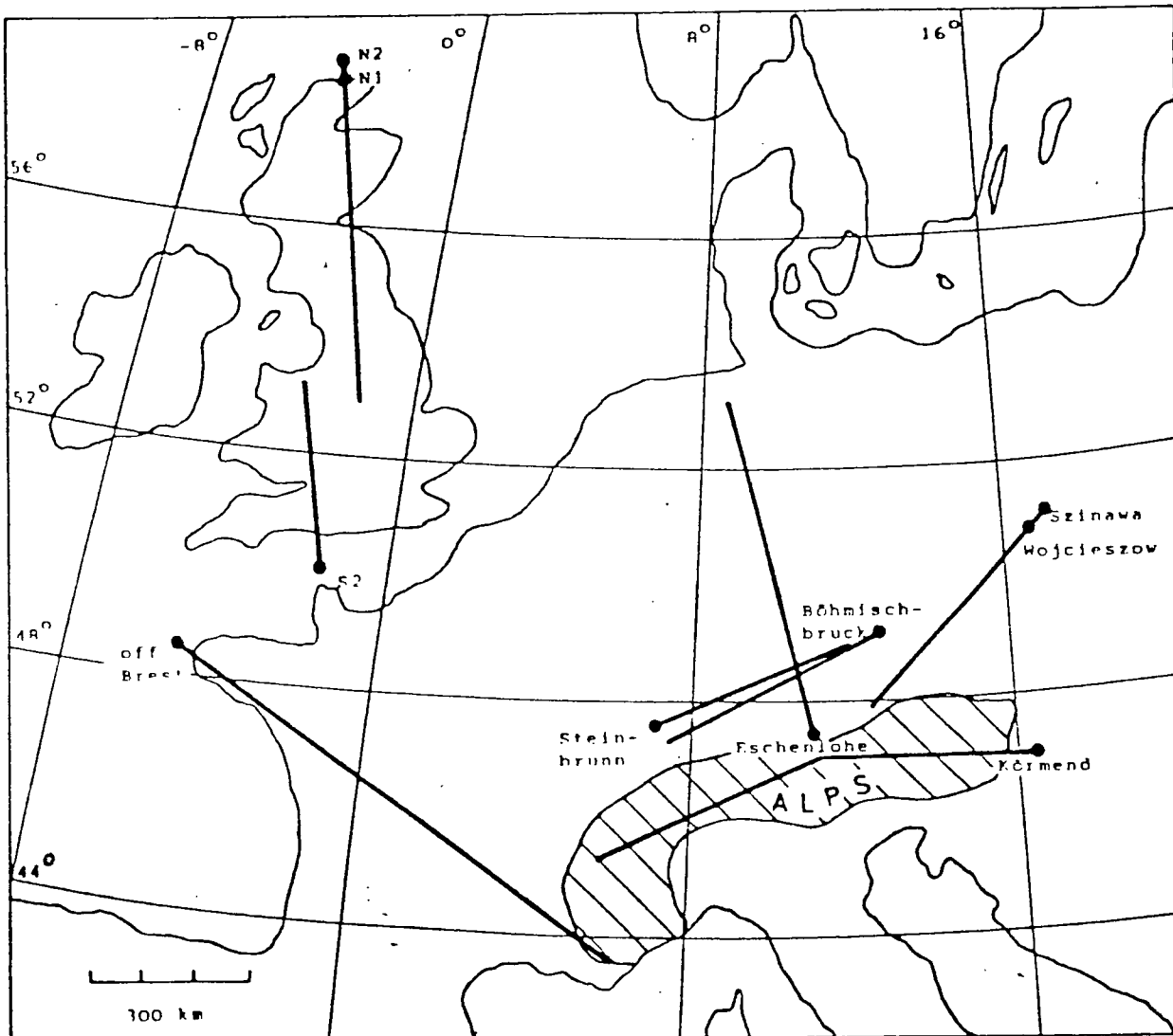


Fig. 5

Long-range profiles in Central and Western Europe for which P_n propagation is discussed in this study. Record sections are reproduced in Figs. 6-10 except for the profile crossing France.

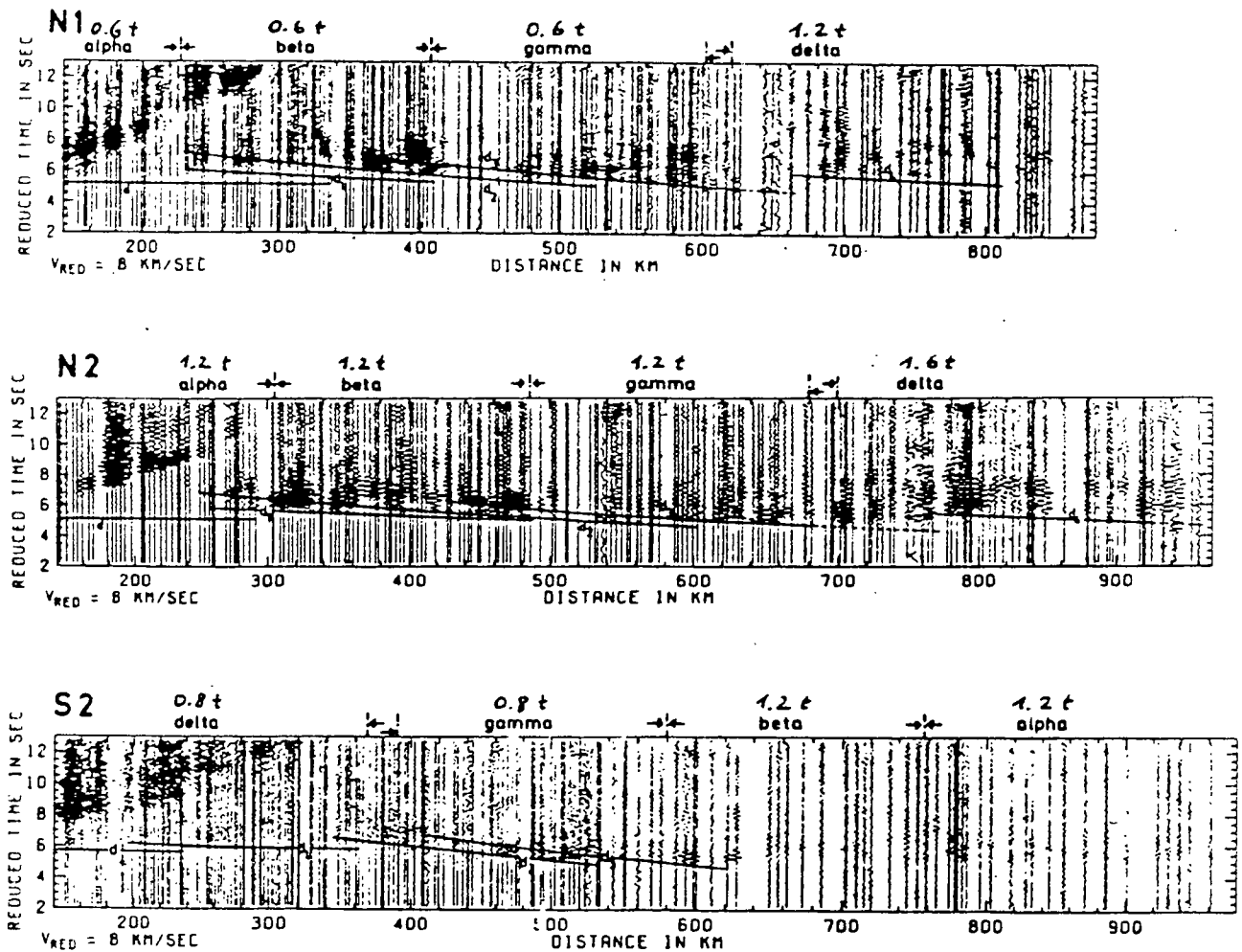


Fig. 6

Long-range profile observations in Great Britain (Faber, 1978). N1 and N2 are profiles with shotpoints at sea north of Scotland, S2 is a reversed profile with shotpoint south of England. The phases labelled d, d_1, \dots, d_4 are parts of the seismic phase P_n . Amplitudes are true amplitudes multiplied by $x^{1.8}$ where x is shotpoint distance. The charge size is indicated for each of the profile segments alpha, beta, gamma and delta.

The two profiles shown in Fig. 7 are located in southern Germany. The first profile (Fig. 7, bottom) runs from Boehmischbruck in eastern Bavaria SW to the southern Black Forest (Emter, 1971; Ansorge *et al.*, 1979). The shotpoint was a quarry located on basement rock, and the charge sizes were 5-7 t. Pn is observed to distances of 400 km with acceptable S/N ratio; stations beyond 400 km are not available. The record section at the top of Fig. 7 is practically a reversed profile. At the shotpoint Steinbrunn in the southern Rhinegraben close to Mulhouse borehole explosions with yields of 0.4-2.8 t were used (Rhinegraben Research Group for Explosion Seismology, 1974). The boreholes did not reach the water table, so coupling of seismic waves into the ground was not optimum. This and the Rhinegraben sediments below Steinbrunn explain why Pn is less well observed than on the profile Boehmischbruck-Steinbrunn.

Fig. 8 shows a record section of the Alpine long-range profile (Alpine Explosion Seismology Group, 1976). The shotpoint was located in western Hungary, borehole explosions with yields of 1, 2 and 4 t were used, and the profile ran 850 km westwards through Austria and the south of Switzerland. It terminated, after bending SW, in the French Alps close to Grenoble. Pn is visible to a distance of 480 km, although partly with poor S/N ratio. Beyond 500 km Pn is completely lost in the noise.

The next example is taken from Burkhardt *et al.* (1976), who recorded several large quarry blasts at Eschenlohe in southern Bavaria on a profile to the north (Fig. 9). The yield of these blasts varied from 12.8 to 21.7 t. A particular feature of the records in Fig. 9 is that absolute particle velocities are available from the information given at the end of the seismograms. Pn is observed with good S/N ratio to a distance of 500 km. The noise level increases by a factor of 5 to 10 when the profile at a distance of 520 km reaches the thick sediments of northern Germany. As a consequence, Pn cannot be identified beyond 540 km.

We finally show in Fig. 10 record sections from the international profile VII which runs NE-SW from Poland through Czechoslovakia and Bavaria into the Alps. Borehole explosions of about 1 t were used at the shotpoints Szinawa and Wojcieszow. The shots at Szinawa produced very clear Pn arrivals at stations in Bavaria from 350 to 420 km. Around 400 km the S/N ratio is approximately 4:1, and absolute Pn amplitudes are about 0.4 μ /s at frequencies from 4 to 8 Hz. Pn observations in Bavaria from shotpoint Wojcieszow, at distances from 290 to 390 km, are less clear. Detection of Pn, however, is still possible at the largest distances.

A general conclusion from the record sections for shots in quarries and boreholes is that Pn was observed to distances of 400 to 500 km; in this conclusion we disregard the Steinbrunn-Boehmischbruck profile (Fig. 7 top) whose weak Pn arrivals are explained by bad shot coupling conditions, as mentioned above. We conclude further: under improved noise conditions, e.g. those which would apply to carefully selected borehole stations of regional networks suggested for monitoring test-ban treaties inside the United States of America and the USSR (Sykes *et al.*, 1983), Pn from a 5 t explosion would have been safely observed in each of the cases shown at least to a distance of 500 km. In the case of Fig. 9 this conclusion would imply that a noise reduction by a factor of 2 to 4 would allow a similar yield reduction and thus bring the yield to the desired 5 t; a

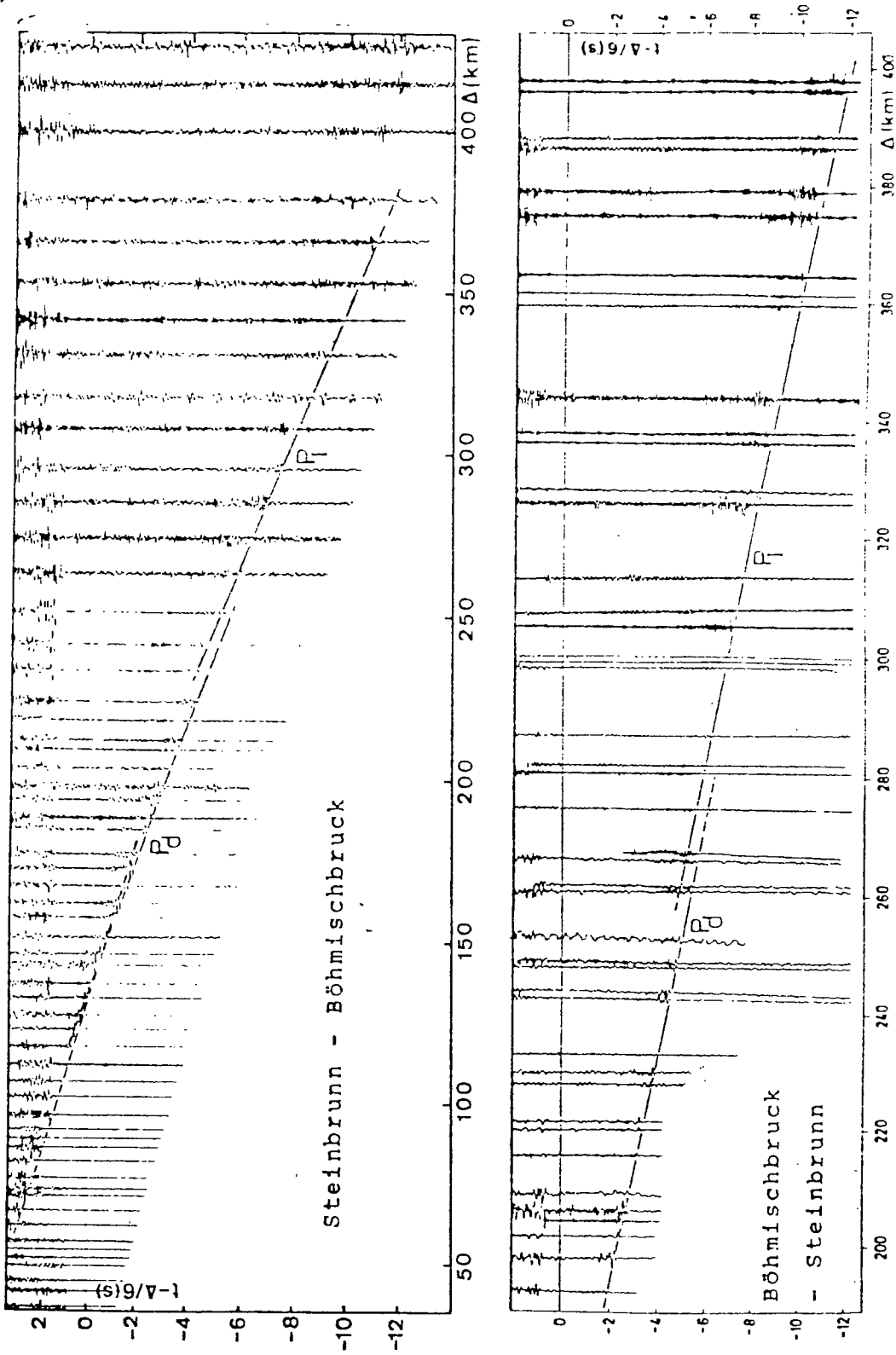


Fig. 7 Long-range profile observations in southern Germany (Ansoerge et al., 1979). The phases P_d and P_i together are called here P_n. The magnifications of the traces have been chosen individually; amplitudes cannot be compared from trace to trace. Distance scales are different in the two sections. The shots at Böhmisschbruck were 5-7 t quarry blasts, the shots at Steinbrunn 0.4-2.8 t borehole explosions above the groundwater table.

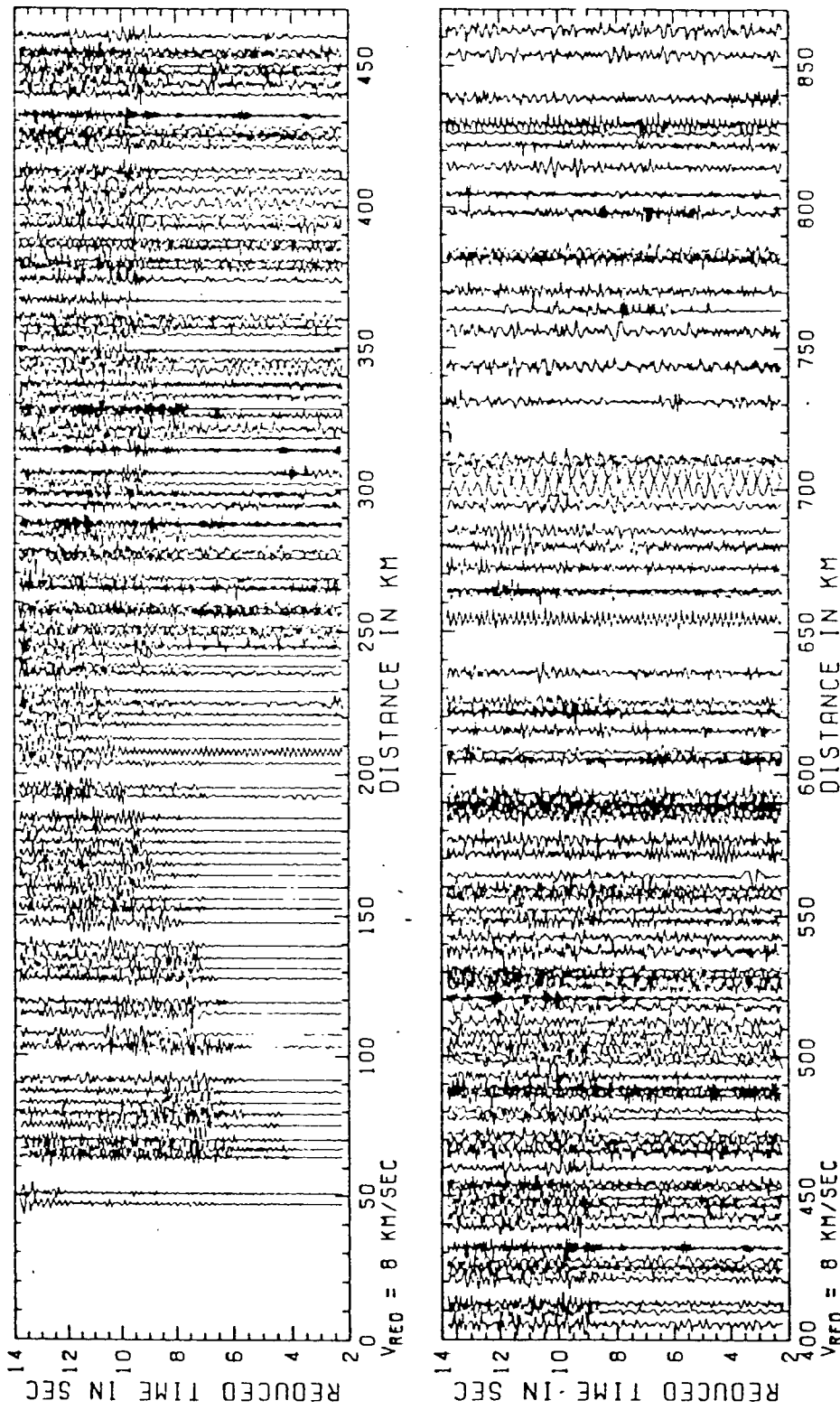


Fig. 8 Long-range profile observations in the Alps (Alpine Explosion Seismology Group, 1976). The profile is directed roughly east-west, starting at Körmend in western Hungary. Borehole explosions of 1, 2 and 4 t were used. All traces are normalized separately and have the same maximum amplitude; the top part and the bottom part of the record section overlap. All recorded seismograms are shown, and no processing except bandpass filtering from 1 to 12 Hz was applied. P_n has reduced arrival times of about 9 s.

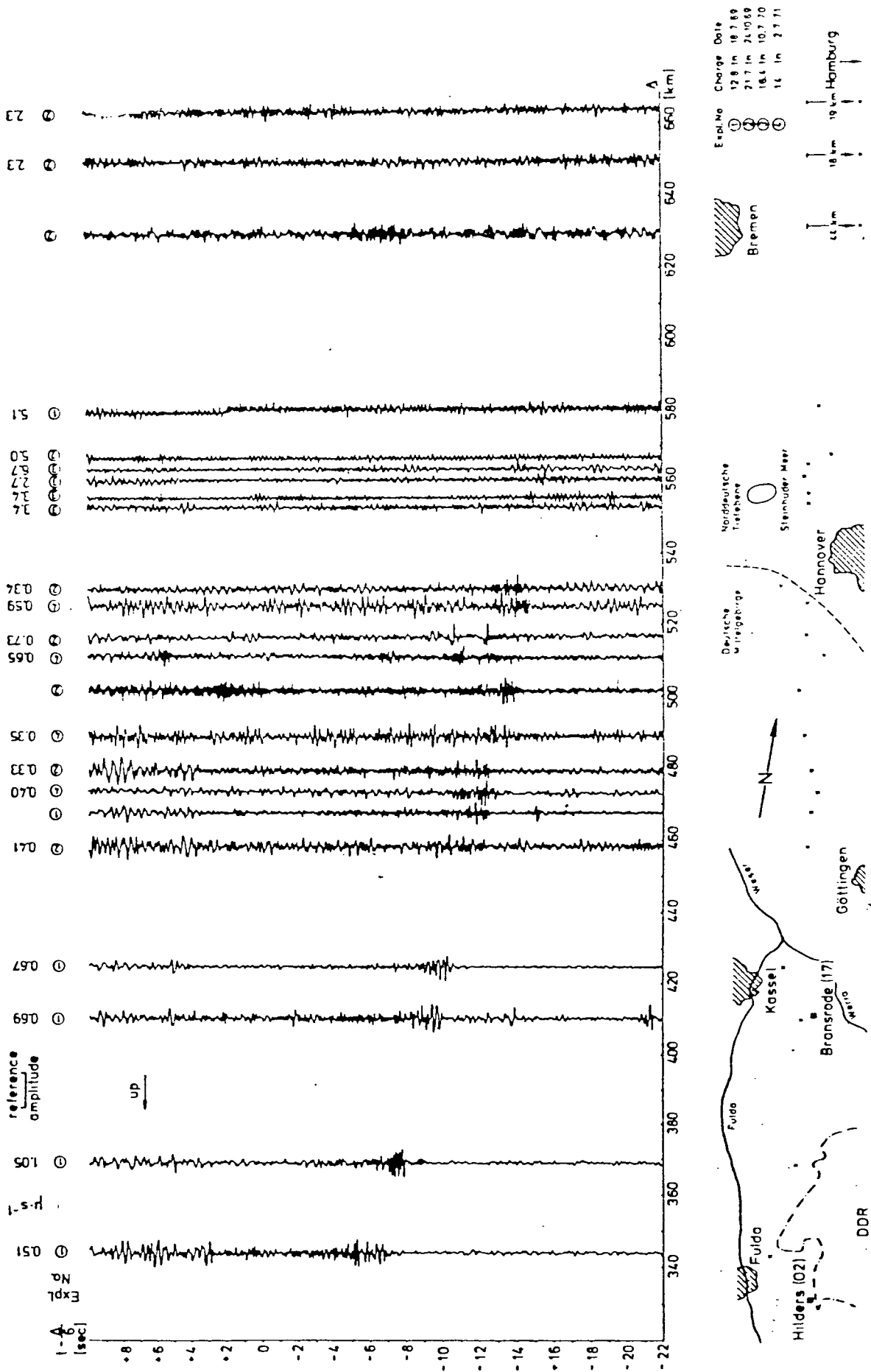


Fig. 9 Long-range profile observations, on a south-north profile through West Germany (Burkhardt et al., 1976). The shots were quarry blasts at Eschenlohe at the northern boundary of the Alps; charge sizes are given in the legend. The traces are absolute particle-velocity seismograms; the numbers at the end of the traces are particle-velocity values in μ/s corresponding to the reference amplitude shown.

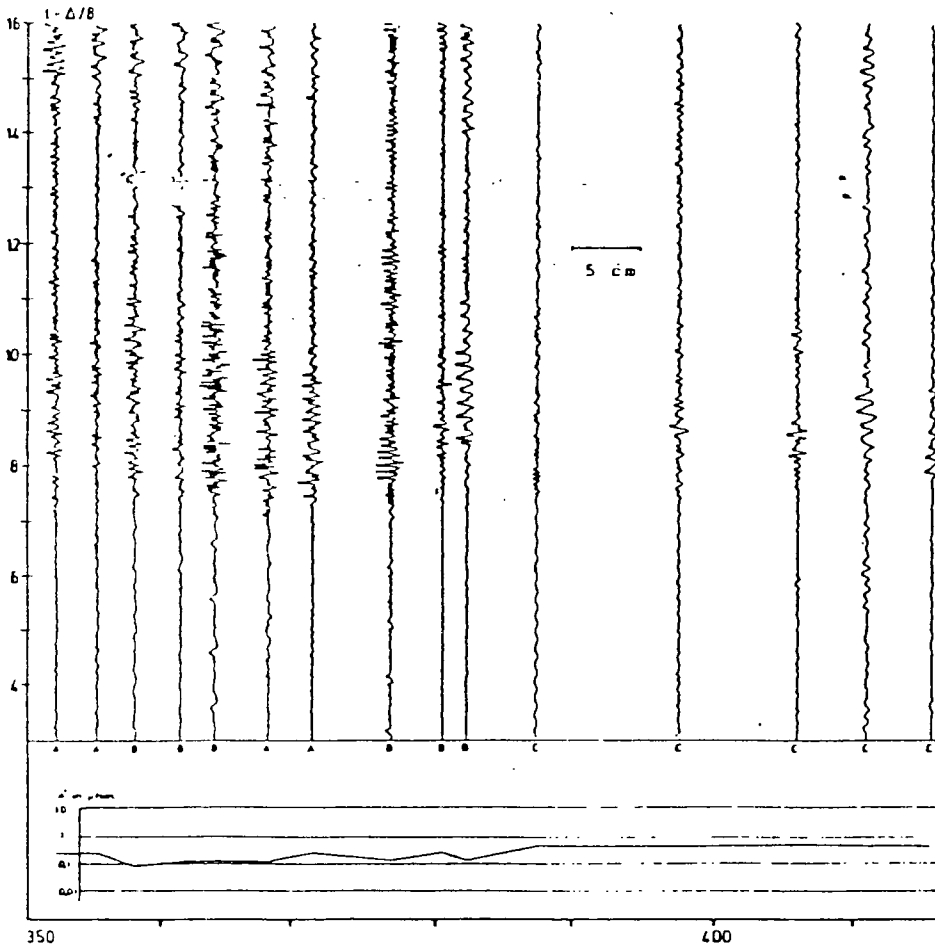
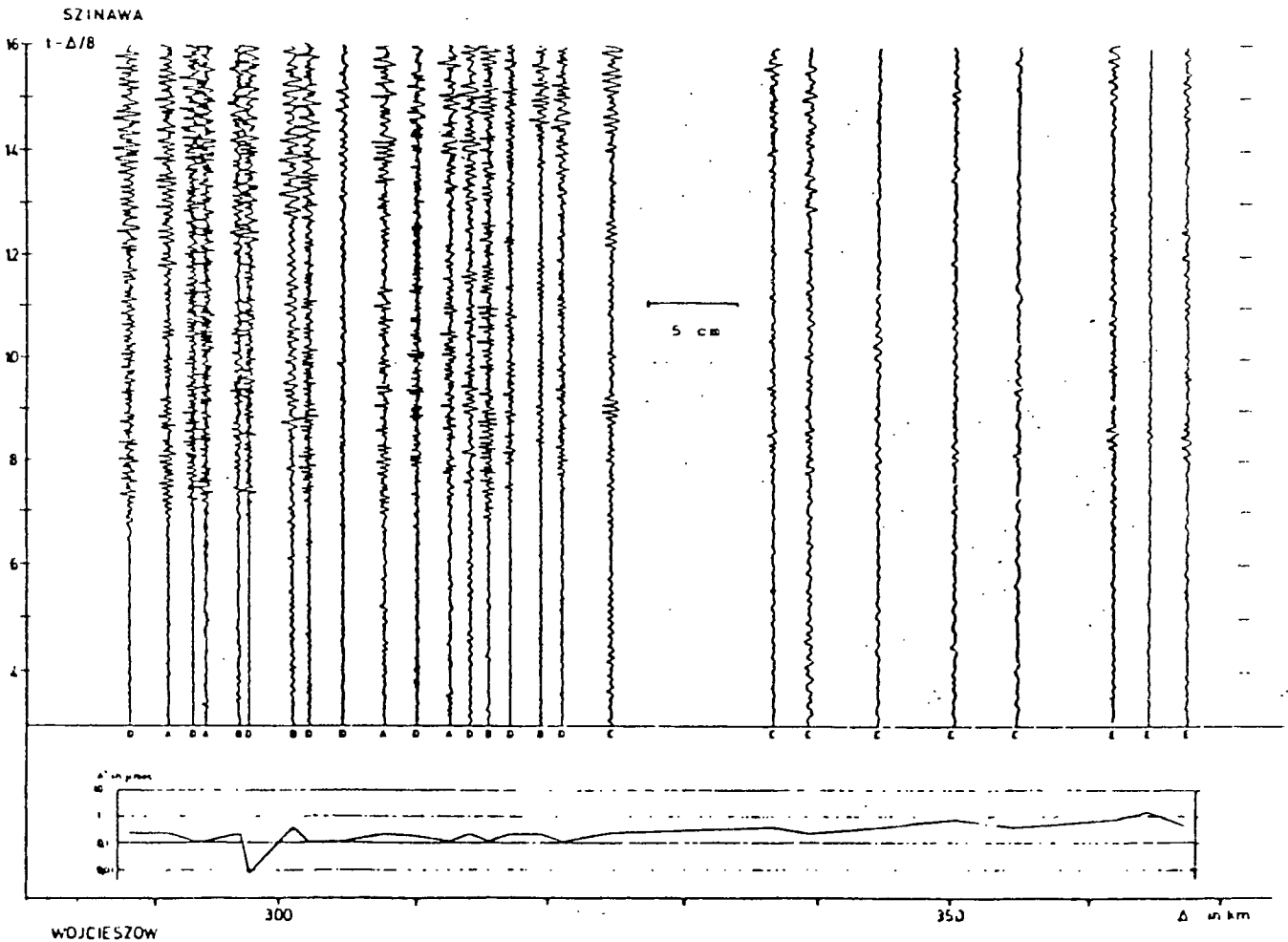


Fig.10 Long-range profile observations on international profile VII, running SW from Poland towards the Alps (record sections made available by Dr. H. Gebrande, Institut für Allgemeine und Angewandte Geophysik, Universität München). Charge sizes of borehole explosions were 1.2 t at shotpoint Szinawa (top) and 0.5-1.0 t at shotpoint Wojcieszow (bottom). Absolute particle velocities in M/s are obtained by multiplying the trace amplitudes in cm (see scale) with the factor A^* given below the sections.



noise reduction by a factor of 2 to 4 due to borehole installation of seismometers is no excessive assumption at all, considering noise conditions downhole and on the surface as given for example in GSE/FRG/17, (1984) for Northern Germany.

Our final aim was to estimate the distance range over which Pn would be observed for a decoupled 1 kt nuclear explosion in salt or, equivalently, for a 5 t tamped explosion in salt. The long-range profiles with excitation by underwater explosions that were discussed above (seismogram examples in Fig. 6) give maximum Pn distances from 700 to 1,400 km, the profiles with excitation by quarry blasts or borehole explosions give maximum Pn distances of 500 km or more. Which of the two excitation conditions on long-range profiles is closer to the conditions of a tamped explosion in competent salt is unknown. In order to be on the safe side, we choose 500 km as the maximum distance to which Pn from a tamped 5 t explosion or a decoupled 1 kt nuclear explosion can be recorded safely if the noise level at a seismic station is 10 nm/s or below. This is roughly 10 times lower than in the left part and 100 times lower than in the right part of the record section in Fig. 9. Stations at carefully selected sites may well reach these low noise amplitudes, especially if the seismometers are located on hard rock. This can easily be derived from the noise amplitudes reported by the stations during the GSETT as well as from the noise conditions of several stations in the Federal Republic of Germany.

On sediments the noise conditions at the surface are much worse. By installation of the seismometers in boreholes at depths of 300 m to 400 m the noise amplitudes can be lowered to 10 nm/s and less (GSE/FRG/17, 1984). A comprehensive test ban or a threshold test ban with a much lower threshold than the currently agreed upon 150 kt, will require internal stations in the United States of America and the USSR. The design of these regional networks depends critically on the detectability of presumed decoupled explosions. This subject is discussed in detail by Sykes et al. (1983) for the USSR. These authors analyse an extended network, consisting of 25 internal and 15 external stations, the internal stations being mainly distributed to monitor those zones of the USSR where salt domes or salt deposits occur. Their analysis assumed a maximum detection distance for a decoupled 1 kt explosion of only 250 km. This assumption is based on one piece of evidence, the observation of the partly decoupled 0.38 kt explosion STERLING which was recorded at 111 km, but not at 240 km. The evidence from many long-range profiles presented here shows that a more realistic and nevertheless conservative estimate for the maximum detection distance is 500 km. We hope that the Sykes et al. analysis will be repeated with this number. For the time being we conclude that networks, having station distances of 500-1,000 km in zones with salt domes or salt deposits, allow monitoring nuclear explosions at the 1 kt (decoupled) level.

5.3 High-frequency decoupling

The discussion of detection of Pn from decoupled nuclear explosions in the foregoing section has been restricted to the frequency range 1-10 Hz which is the range usually observed on long-range profiles in refraction seismology. In this frequency range decoupling is assumed to be strong, as illustrated by the decoupling factor of 200 used here. Decoupling at higher frequencies is considerably less: at 30 Hz the decoupling factors according to Figs. 1-4 span the range 3 to 20. It has been discussed (Blandford, 1982; Glenn, 1984; Glenn et al., 1985) or strongly suggested (Evernden et al., 1984) to use high-frequency observations of seismic waves for monitoring decoupling attempts.

The problem with this suggestion is that it is not known at present whether absorption of Pn is low enough for observation of 30 Hz components above the noise level. This question requires detailed observational studies at high frequencies. From current knowledge it appears that the weaker high-frequency decoupling can possibly be exploited for monitoring decoupled explosions over certain favourable propagation paths (Glenn et al., 1985), but not in general.

The regional networks in the United States of America and the USSR should be constructed according to the requirements for detection of Pn in the 1-10 Hz frequency range, as specified in the foregoing section. However, the instrumentation should record broadband at least to 30 Hz, such that high-frequency monitoring could be employed in case it turns out to be feasible.

6. Conclusion

Decoupling of nuclear tests in large salt cavities appears to be technically feasible for yields of 1 kt to several tens of kt. Seismic monitoring of the Pn waves of such tests is likewise possible, provided that station distances are 500-1,000 km in areas where salt in the form of domes or sufficiently thick deposits occurs. Stations have to be sited in boreholes at places with very low noise. For optimum construction of networks of such stations in nuclear weapon states it is mandatory that relevant information on geology and seismic noise conditions is available.

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CONFERENCE ON DISARMAMENT

CD/625
31 July 1985
ENGLISH
Original: RUSSIAN

LETTER DATED 31 JULY 1985 ADDRESSED TO THE PRESIDENT OF
THE CONFERENCE ON DISARMAMENT FROM THE REPRESENTATIVE OF
THE UNION OF SOVIET SOCIALIST REPUBLICS TRANSMITTING THE
TEXT OF THE STATEMENT MADE BY THE GENERAL SECRETARY OF
THE CPSU CENTRAL COMMITTEE, MIKHAIL GORBACHEV CONCERNING
THE ANNOUNCEMENT BY THE SOVIET UNION OF A UNILATERAL
MORATORIUM ON ALL NUCLEAR EXPLOSIONS FROM 6 AUGUST 1985
TO 1 JANUARY 1986

I have the honour to transmit herewith the text of the statement made by the General Secretary of the Central Committee of the CPSU, M.S. Gorbachev, concerning the announcement by the Soviet Union of a unilateral moratorium on all nuclear explosions from 6 August 1985 to 1 January 1986.

I request you to arrange for its distribution as an official document of the Conference on Disarmament.

(signed) V. Issraelyan

GE.85-63368

STATEMENT BY M.S. GORBACHEV, GENERAL SECRETARY OF THE
CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE
SOVIET UNION

Moscow, 29 July (TASS). The continuing nuclear arms race involves tremendous dangers for the future of world civilization. It is leading to increasing tension in the international arena and a growing military menace, while diverting colossal intellectual and material resources from constructive purposes.

From the very beginning of the nuclear age, the Soviet Union has waged a consistent and vigorous struggle to halt the accumulation of nuclear arsenals, restrain military rivalry, and strengthen confidence and peaceful co-operation among States. This has been the aim of all the very extensive activities of the USSR in the framework of the United Nations, and in multilateral and bilateral negotiations on the limitation and reduction of armaments. The Soviet Union is not seeking military superiority; it favours the maintenance of the balance of military forces at the lowest possible level.

It is our conviction that the cessation of all nuclear weapon tests would be an important contribution to the strengthening of strategic stability and peace on earth. It is no secret that even more dangerous kinds and types of weapons of mass destruction are developed and perfected in the course of such tests.

In the interests of creating favourable conditions for the conclusion of an international treaty on a general and complete prohibition of nuclear weapon tests, the USSR has repeatedly proposed to nuclear-weapon States to arrange a moratorium on all nuclear explosions, starting from a mutually agreed date. Regrettably, it has not yet proved possible to take this important step.

In an endeavour to facilitate the cessation of the dangerous competition in the build-up of nuclear arsenals and desiring to set a good example, the Soviet Union has decided to halt unilaterally all nuclear explosions starting from 6 August this year. We call upon the Government of the United States to cease its nuclear explosions as from the same date, which is marked throughout the world as the day of the tragedy of Hiroshima. Our moratorium is proclaimed till 1 January 1986, but it will continue in effect beyond that date if the United States, for its part, refrains from carrying out nuclear explosions.

There is no doubt that a mutual moratorium by the USSR and the United States on all nuclear explosions would serve as a good example also for other nuclear-weapon States.

The Soviet Union expects the United States to give a positive response to this initiative and to halt its nuclear explosions.

This would meet the aspirations and hopes of all peoples.

JAPAN

CONCRETE MEASURES FOR THE REALIZATION OF THE
INTERNATIONAL SEISMIC DATA EXCHANGE SYSTEM

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1. Introduction

In order to realize the International Seismic Data Exchange System, it will be necessary to examine technical, administrative and financial aspects of the System in the light of the results of scientific and technical studies made up to now by the Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events.

Japan has already presented the Working Paper CD/389 indicating the requirements for an effective functioning of this System. It must now be made clear what kind of concrete measures will be needed to meet these requirements. Drawing upon the results of the first, second and third Reports of the Group of Scientific Experts, this Working Paper attempts to identify those concrete measures that are indispensable to an effective function of the System. It also gives a preliminary estimate of the financial costs of these measures.

2. Basic ideas in identifying the measures

A most realistic and effective measure of verification of a nuclear test ban will require the following two steps:

- (1) To begin with, to establish a multilateral verification system with the highest possible degree of confidence on the basis of the existing and available facilities and equipments.
- (2) To proceed to improve continuously the verification capabilities with a view to reaching the final goal: a system capable of detecting and identifying with high degree of confidence an underground nuclear explosion of any kind, at any place.

3. Required measures

3.1 Seismograph stations and stations network

(The network model is based on the Network III (SRO) in the CCD/558)

3.1.1 Arrangements for the seismic observation

(a) Digitalization of seismograph system

It is necessary to change the analogue recording method into the digital recording method, preferably broadband with high dynamic, at the following Stations:

- Most of the stations on the African continent;
- Some stations in the South Pacific, the Antarctic, and the Arctic.

The digitalization can be accomplished by procuring or modifying the following equipments:

- analogue-to-digital converter;
- signal detector;
- digital recorder;
- analysing equipment.

(b) Standardization of observation equipments

Observation equipments of each seismic station should meet the requirements for "single station" (optimal variant) or "array station" described on the table 8.1 of CCD/558. (Computer for data processing at each station should be identical or can be functioned by means of a common computer program language.)

(c) Distribution of an operational manual

The standard operation manual including the following procedures should be made by the GSE and distributed to each station;

- Analysing the recorded signals and extracting Level I parameters;
- Correcting for instrument response;
- Maintaining and ensuring calibration integrity;
- Responding promptly to requests from an international data centre;
- Keeping all data at least one year at each station.

(d) Distribution of computer programs for data processing

The common computer programs for data processing should be prepared and distributed likewise.

(e) Periodical calibration measurement of seismic devices of each station

As it is necessary to carry out the calibration measurement at least twice a year (see CD/43, page 14), a standard procedure for the calibration of observation equipments should be determined and be followed by each station.

3.1.2 Maintenance of observation function

(a) Prevention of interruption in function

Following measures should be taken:

Establishment of back-up observation points,

- Duplicating the short MTBF (Mean Time Between Failure) equipment;
- Measures for shortening MTTR (Mean Time to Repair) of equipment;
- Spares for maintenance.

(b) Requirements for maintenance

- Maintenance technicians;
- Tools and equipments for maintenance.

3.1.3 Improvement of the detection and the identification capability of the International Seismic Data Exchange System

(a) Sophistication of the performance of stations

The emphasis should be placed on the following stations:

- Stations on the African continent;
- In the South Pacific;
- On the South American continent.

(b) Enhancement of the observation capability in the ocean areas and their vicinities

It is necessary to take the following measures:

- Installation of ocean-bottom seismographs on the ocean floor or in a borehole on the ocean floor;
- Development of special system deployed for T-phase detection.

The GSE shall examine the positions and the State parties will jointly or individually install and operate these seismographs. The State parties shall jointly develop these sensors.

(c) Measures for high-noise level areas

If these are seismographs located in high-noise level areas, they should be moved to more appropriate places.

The State party in which such a station is located should move it.

(d) Reinforcement of the observation capability covering the areas for traditional nuclear explosion tests.

It is necessary to constitute the special detection networks with remote seismic sensors deployed on the observation points around the nuclear test sites. These points should be determined by computer simulation or by other methods and integrated into the International Seismic Data Exchange System.

The State parties shall jointly install and operate the network.

(e) Supplementary measure for special areas

It is also necessary to examine the possibility of establishing special networks for detecting underground nuclear tests in the areas where the impact of the explosion can be sharply reduced because of geological or tectonic natures. (Salt cavity, dry alluvium, etc.)

3.2 Level I data extraction

3.2.1 Rationalization of the process of exchanging data

(a) Specification of the parameters to be exchanged

The list of parameters to be exchanged should be specified on the basis of the GSE studies. And it is necessary to establish a procedure for addition and modification in the list in the course of the actual operation.

(b) Research and development, of filter techniques and others, for Level I data extraction

It is necessary to make research and develop filter techniques such as the polarization filtering technique.

The State party shall voluntarily develop and propose techniques to the GSE.

3.2.2 Automation of data extraction

(a) Promotion of the automation of data extraction

Automatic extraction of seismic parameters is very desirable for reducing workload of operators.

Following actions will be needed:

- Installation of a mini-computer for automatic extraction at each station;
- Development of a unified algorithm for automatic extraction.

The State party should facilitate the automation and exchange information about the algorithm.

(b) Complementary measure for automatic extraction

Programmer-seismologists should be stationed at each station.

The State party should station these personnel.

3.3 Exchange of Level I data through the WMO/GTS

3.3.1 Communication between the seismic stations and the GTS station

Communication between the seismic stations and the national GTS station should be established by the State party in accordance with the circumstances of each State.

3.3.2 Communication between national GTS stations and International Data Centres (WMO/GTS)

(a) Improvement of low-speed circuits in the WMO/GTS network.

In order to transmit a required amount of Level I data, and taking into account the future increase of data, improvement of the following low-speed circuits of WMO/GTS network should be made as early as possible:

- Western and southern part of Africa;
- South-west part of Asia;
- Some part of South America;
- Some part of the South-west Pacific region.

The CD shall request the WMO to take necessary actions.

(b) Improvement of manually operated centres of WMO/GTS

Relaying of seismic data from a GTS centre to another or to an IDC should be made automatically in order to reduce handling time at the GTS centre.

In this regard, centres in the following areas need automation:

- Africa;
- South America;
- Eastern Europe.

The CD shall request the WMO to take necessary actions.

(c) Transmission format of Level I data

On the basis of the GSE studies, the final transmission format of Level I data from seismic stations to International Data Centres should be determined.

(d) Familiarization of personnel at GTS stations

An operational manual for the personnel working at GTS stations should be made and the personnel should familiarize itself with handling the Level I data.

The CD shall request the WMO to take necessary actions.

3.4 Level II data exchange

3.4.1 Communication for Level II data exchange

(a) Arrangement for Level II data transmission

The most appropriate measure for Level II data transmission should be adopted by each State party according to its circumstances, taking into account the options recommended in the CD/448.

(b) Arrangement for communication

In the case of digital data communication, the required softwares should also be prepared by the parties concerned through consultation.

3.4.2 Level II data analysis

(a) Standard Level II data analysis procedure

The following should be provided for Level II data analysis by each State party:

- Standard procedure for Level II data analysis;
- Unified softwares for the data processing computer;
- Operation manual for analyst.

(b) Reinforcement of Level II data analysis capability of each State party

- Employment of well-trained analysts;
- Devices for analysts.

3.5 International Data Centres

3.5.1 Facilities and equipment for the operation of the International Data Centres

The necessary actions should be undertaken by the State parties in which IDC is located. The expenditure required for the actions should be borne by all State parties.

(a) Establishment of required facilities

Certain facilities such as building, electric power supply, air-conditioning apparatus are necessary.

(b) Installation of communication equipment and other related devices

In order to carry out the telecommunication promptly and certainly, each IDC should install the following equipments and devices:

- communication equipments;
- communication terminal equipments;
- software for data telecommunication.

(c) Installation of equipments for processing, analysis and storage of data

In order to carry out processing, analysis and storage of data, IDC should install the following equipments:

- a large scale speedy data processor;

- sufficient and adequate memory units;
- control terminals;
- back-up equipments including an alternate computer.

3.5.2 Maintaining the continuity of IDC operation

(a) Employment of sufficient number of personnel

It is necessary to employ a sufficient number of the following qualified personnel:

- seismologist;
- maintenance technician;
- programmer;
- administration staff.

(b) Duplication of major equipments

In order to operate the IDCs without interruption even in case of major equipment failure, the system should be duplicated.

3.6 Assessment of the verification capability of the International Seismic Data Exchange System

3.6.1 Assessment of the initial capability of the System

(a) Estimation of computer simulation

The initial verification capability of the System should be estimated, in the first instance, by computer simulation. For this purpose, an adequate simulation model needs to be developed and the relevant information should be collected as much as possible.

The GSE shall undertake the estimation.

(b) Correction of the assessment by the results of technical tests

The results of technical tests should be used for the correction of the assessment.

(c) Reassessment after the comprehensive experimental exercise of the System

3.6.2 Continuous evaluation during the actual operation

The verification capability should be continuously monitored and evaluated by a special organ. In particular, in case of change or improvement of elements of the system, a special evaluation should be carried out.

(b) Equipment

Borehole seismograph system:

- borehole	\$US 188,000
- sensor	\$US 100,000
- telemeter equipment	\$US 38,000

Digitalization (as mentioned in (a)) (\$US 88,000)

Computer for digital data processing \$US 1,542,000

Total cost without digitalization \$US 1,868,000

Total cost including digitalization \$US 1,956,000

(c) Total cost for 23 stations:

Without digitalization

23 x \$US 1,868,000 = \$US 42,968,000

Including digitalization

23 x \$US 1,956,000 = \$US 44,988,000

(d) Additional requirements of personnel:

2 telemeter technicians at each station

4.2.3 Distribution of computer programs for data processing

Preparation of common computer programs \$US 292,000

Magnetic tapes for distribution (very small amount)

4.2.4 Employment of personnel for continuous operation

Additional requirement of personnel for continuous data exchange operation: 12 at each station

4.2.5 Prevention of interruption in function

Establishment of a back-up observation point:

- borehole	\$US 188,000
- sensor	\$US 100,000
- telemeter equipment	\$US 38,000

Spare sets of integral circuit x 3

3 x \$US 38,000 = \$US 144,000

Total cost for one station \$US 440,000

4.2.6 Requirements for maintenance

(a) Additional requirement of personnel:

2 maintenance technicians at each station

(b) Tools and equipments for maintenance:

2 unit x \$US 29,000 = \$US 58,000

(c) Required expenditure (cannot be estimated)

(d) A travelling maintenance team:

Technicians: 8

Travelling expenses per year: \$US 25,000

4.2.7 Automation of data extraction

(a) Equipments and its costs per station:

Mini-computer for automatic data extraction: \$US 2,771,000

Software for the automatic data extraction: \$US 2,500,000

Total cost: \$US 5,271,000

(b) Additional requirement of personnel:

6 programmer-seismologists at each station (for the countries where seismic events occur not frequently);

12 programmer-seismologists at each station (for the countries where seismic events occur frequently).

4.2.8 Communication between the seismic station and the GTS station for Level I data transmission

The cost of the establishment of the communication measure varies from country to another. In the case of Japan for example,

Data transmission and receiving equipments)	
)	
Terminal equipments)	\$US 75,000
)	
Software for data transmission)	
Acquisition of an exclusive line	\$US 25,000
Total cost	\$US 100,000

4.2.9 Communication for Level II data exchange

(a) Postal service

The airmail postage of a magnetic tape or
a diskette for one interval \$US 300

(b) International telephone service

Terminal unit, computer and software \$US 125,000

Telephone charge per year \$US 4,200

4.2.10 Reinforcement of Level II data analysis capability of each State party

(a) Equipments and costs for one participant

Hardware for data analysis \$US 2,771,000

Software \$US 2,500,000

Total cost \$US 5,271,000

(b) Requirement of personnel

6 analysts for each participant

4.2.11 International Data Centres

(a) Equipment and costs for one IDC

Communication equipment and required software \$US 170,000

Equipment for data processing (computer,
recording units and software) \$US 16,667,000

Total cost for one IDC \$US 16,837,000

(b) Total cost for 3 IDCs

3 x \$US 16,837,000 = \$US 50,511,000

(c) Requirement of personnel for one IDC

8 seismologists

8 maintenance technicians

10 programmers

10 personnel for bulletin

5 administration staff

Total personnel for one IDC: 41

(d) Annual operational cost

Annual cost for 3 IDCs:

$$3 \times \text{\$US } 1,010,000 = \text{\$US } 3,030,000$$

4.3 Estimated costs and personnel required for improving the detection and the identification capability of the system

4.3.1 Sophistication of the performance of stations

(a) Number of stations to be ameliorated

We assume that 10 type-II stations should be modified to type-III stations (small array with 6 observation points) in order to improve the capability of the system as a whole.

(b) Cost for the modification of one station

Cost for one observation point:

Borehole (depth: 200 m)	\$US	188,000
Sensor	\$US	100,000
Telemeter equipment	\$US	38,000
Total	\$US	326,000

Cost for one small array station (6 points)

$$6 \times \text{\$US } 326,000 = \text{\$US } 1,956,000$$

Hardwares of array centre	\$US	3,358,000
Softwares of array centre	\$US	3,333,000
Total cost	\$US	8,647,000

(c) Cost for the modification of 10 stations:

$$10 \times \text{\$US } 8,647,000 = \text{\$US } 86,470,000$$

4.3.2 Enhancement of the observation capability in the ocean areas and their vicinities

(a) Number of ocean-bottom seismographs to be installed

We assume that 10 ocean-bottom seismographs should be installed in the following areas:

- 5 in the Pacific Ocean;
- 3 in the Indian Ocean;
- 2 in the Atlantic Ocean.

(b) Cost for the installation of one seismograph	
Sensors (short period, Z, N, E, x 4)	\$US 3,750,000
Cable	\$US 4,375,000
Cost for the installation	\$US 1,875,000
Ground environment	\$US 830,000
Total cost	\$US 10,830,000

(c) Cost for the installation of 10 seismographs

$$10 \times \$US 10,830,000 = \$US 108,300,000$$

(d) Operation cost for 10 systems per year

$$0.006 \times \$US 830,000 = \$US 49,800$$

4.3.3 Measures for high-noise level areas

(a) Removal costs for one seismic station

Sensor	\$US 100,000
Borehole	\$US 188,000
Communication equipment: (transmitter)	\$US 38,000
(receiver)	\$US 38,000
Total cost for one station	\$US 364,000

4.3.4 Reinforcement of the capability covering the areas for traditional nuclear explosion tests

(a) Areas to be covered

We assume that 6 (average) seismographs should be established around the traditional nuclear test site areas for detecting very small seismic events, and observation data should be transmitted by telemetry (if necessary, by satellite communication).

4 test areas on the northern Eurasian continent

1 test site area in North America

1 test site area in Asia

1 test site area in the South Pacific

Total 7 test site areas and 42 seismographs

FEDERAL REPUBLIC OF GERMANY

Working Paper

Verification of the non-production of chemical warfare agents
by means of inspections in the civilian chemical industry

I. General aspects

Under a convention prohibiting chemical weapons, the branches of the civilian chemical industry relevant to the verification of non-production would be subjected to systematic international inspections. The scope of surveillance would depend to a large extent on the substances selected and their significance for civilian purposes, and on the intensity of the actual inspection procedures. The inspections can apply in the industrial sector both to producers, manufacturing industries, and end users.

This paper surveys the range of substances involved and the scope of surveillance and outlines the industrial sector that would have to be covered. After the entry into force of a convention those substances would be selected products of chemicals factories which would be subject to regular inspections to prevent their possible misuse for the manufacture of chemical weapons.

II. Scope of substances

1. General

The choice of substances for non-production inspections may cover products usable exclusively for chemical warfare (single-purpose agents), characteristic key precursors for their production, and substances that are of both military and civilian significance (dual-purpose agents).

However, in order to ensure adequate verification whilst keeping inspections within reasonable limits, generally recognized criteria are needed for the selection of substances and their incorporation in the various inspection procedures.

2. Criteria for the selection of substances

One objective basis for the selection of substances are the toxicity criteria for supertoxic lethal, other lethal and other harmful chemicals as defined by the Conference on Disarmament for the purposes of a convention banning chemical weapons. Another should be the assessment of the potential military threat posed by a chemical substance.

The proposed convention should contain a definition of the term "key precursors". In the opinion of the Federal Republic of Germany the precursors in the final technical reaction stage of the production of supertoxic lethal weapons which are characteristic for the toxicity of the end-product should be defined as key precursors. The final technical reaction stage would be determined by the intermediate product which can still be subjected to quantitative inspections in the manufacturing process. This definition is already contained in working paper CD/439 on the transfer problem submitted by the Federal Republic of Germany in 1984.

This definition encompasses only key precursors that are particularly harmful. The key precursors thus defined are generally only used to a very limited extent for civilian purposes. Given the small number of producers, the scope of the inspections will be kept within reasonable limits.

Notwithstanding this general rule, other precursors could be treated as key precursors if, within the meaning of the convention, they constituted a risk and if the competent body under the convention reaches agreement on this point.

The designated key precursors would be listed and annexed to the convention. No consensus has so far been reached in the Conference on Disarmament on the contents of such a list. Several proposals concerning the chemical products to be included in the list have already been submitted.

3. Supertoxic lethal chemicals and key precursors

The supertoxic lethal chemicals that could be used for chemical warfare have at the present time little civilian significance. They are therefore not produced on an industrial scale for such purposes. Under special convention provisions which would be based on the proposals already worked out in the Conference on Disarmament, their manufacture would be permitted in limited quantities for protective purposes but in a declared, separate facility for this purpose. Consequently, an explicit ban on toxic chemicals and key precursors which are of significance for the production of chemical weapons but for which there is no civilian demand at the present time would appear to suggest itself. Such a ban should be included explicitly in a list and ought to cover any quantities in excess of a production of one metric ton per annum. Should the banned substances acquire a civilian significance justifying their production, on an industrial scale, the competent body under the Convention would have to be notified of the envisaged production. The manufacture and use of such substances would have to be subject to systematic inspections.

The systematic international verification of non-production should consist of an exchange of data as well as on-site inspections on a random basis in companies determined by lot and should be limited to the key precursors for the manufacture of supertoxic lethal chemicals within the meaning of the definition given above because with regard to these substances there is a danger of the convention being circumvented.

Pinacolyl alcohol, for example, might be included in the list in application of the exception-from-the-rule principle. It is of little general use for permitted purposes. If, therefore, it were manufactured in large quantities it would be justifiable to require proof that it is actually being produced for permitted purposes.

In addition to the systematic monitoring of key precursors including on-site inspections, an exchange of data concerning the production and use of certain selected precursors should take place in order to make inspections of particularly dangerous supertoxic lethal chemicals as effective as possible. This might be applied, for instance, to esters of phosphorous acid, which are used on a large scale for civilian purposes or can be produced analogously to esters of phosphoric acid, and similarly to phosphorus trichloride and phosphorus oxychloride as well as the β -substituted derivatives of N, N-dialkylamino ethanes for the production of VX and analogous substances, some of which are used for many different permitted purposes.

Difficulty arises with regard to the question whether the key precursors of mustard gas should be included in systematic non-production verification procedures. A restriction to the key precursor thiodiglykol would be insufficient since there are other modern manufacturing processes without this compound as intermediate product. Really effective monitoring of key precursors of mustard gas would therefore also have to be extended to substances which are produced in large quantities as basic substances by the chemical industry and used for many different purposes. Such comprehensive monitoring would hardly be practicable. It would seem expedient, therefore, to concentrate on an exchange of data regarding thiodiglykol and sulphur chlorides which make for a relatively simple technical process in the production of mustard gas.

In addition, producer countries could agree on export controls if it were established that a country were importing key products for the manufacture of mustard gas.

4. Other lethal substances and precursors

In the Conference on Disarmament other potentially dual-purpose lethal chemicals as well as selected precursors for the production of chemical weapons have been proposed as substances which should fall under non-production verification. Contracting States would only be required to report statistical data.

The proposed substances, which themselves can also be used as chemical weapons, are precursors of a number of civilian products. Every year they are produced in their thousands of tons. This applies principally to hydrogen cyanide, cyanogen chloride, and phosgene. Their potential threat must today be seen in a different light in view of the availability of much more effective chemical and other weapons.

It is therefore doubtful whether it makes sense to include these products in an exchange of data. In so far as their inclusion is envisaged, one should take into account when collecting data concerning their production and use the fact that these chemicals are mass products.

III. Scope of inspections

1. General

The intensity of inspection procedures must be such as to ensure to an adequate degree of certainty that compliance with the contractual undertaking not to produce chemical weapons is systematically and internationally verifiable.

Legitimate interests of the chemical industry can be protected if on-site inspections are carried out without the disclosure of secret technological and industrial information. This could be achieved by the restrictive selection of substances and the application of inspection procedures oriented to the toxicity and potential threat of the substances.

2. Verification of non-production of key precursors

Verification of the non-production of chemical weapons starts from the physical conditions for the production of such weapons. The supertoxic lethal chemicals produced for chemical warfare differ from those used for civilian purposes in that they have a much higher level of toxicity. For their production, therefore, more has to be invested in safety, which is evident in the physical characteristics of the facility. The absence of the safety precautions necessary for the production of supertoxic lethal chemicals becomes obvious upon viewing the premises and is therefore clear proof that such substances are not being produced in the facility.

In the case of less toxic key precursors manufactured for civilian purposes, which have a lower level of toxicity, the absence of extensive safety precautions is not in itself sufficient evidence that they are not being used for the production of chemical weapons. Consequently, the monitoring of these chemicals must also take other criteria into account and be more comprehensive.

Inspections in the production facility should concentrate on the quantity of key precursor produced or, where the processing is continuous, on the output of finished products. The object of the inspection is not the chemical factory as such, only the one relevant and precisely defined substance.

The actual test should take place in the crucial reaction phase. It should begin at the stage in the overall production process immediately preceding the emergence of the key precursor and cover only this phase.

Inspections of key precursors should be conducted on the basis of annual statistical data and on-site inspections if the total annual quantity produced exceeds one metric ton.

To ensure that the manufacturers of key precursors in question receive equal treatment, on-site inspections should be carried out on a random basis. Companies should be determined by lot, with the competent body under the convention fixing every year the percentage of all firms to be subjected to inspections.

The installation of additional measuring instruments by the inspecting agencies to monitor the quantities produced does not appear necessary and would moreover be impracticable.

The inspection, consisting of statistical data, the review of plant records, interviews, viewing of facility areas, as well as sampling and analysis, must ensure reliable verification of the non-production of chemical weapons. However, they should not provide an overall survey of the production process and hence insights into a firm's own manufacturing processes.

3. Inspections relating to the manufacture of key precursors

The systematic verification of non-production in the chemical industry should serve to confirm that quantities of key precursors that are declared to be intended for permitted purposes are actually used as stated in the information given. Such inspections must therefore be sufficiently accurate and reliable. This is relatively simple in the case of key precursors which, as intermediates, are directly and completely further processed in the same facility. The procedure becomes even more straight forward where the key precursor goes through a continuous and automatic reaction process without being isolated. This will mostly be the case with substances that are produced in large quantities for a finished product for which there is a consistently high demand.

Key precursors with a wide range of uses are sold to other domestic firms or exported for further processing more often than those the use of which as intermediates applies to only a few finished products. The supply of such key precursors to manufacturers makes inspection procedures more difficult and costly. In order to ensure their effectiveness they would have to be extended to the facilities of manufacturers both at home and abroad.

In order to limit the number of companies affected, only those who receive quantities of key precursors in excess of one metric ton per year should fall within the scope of inspections. On the one hand, fixing a much higher limit would include the risk of companies' spreading the processing among several plants to keep below the limit. Moreover, it might give rise to unjustified mistrust where a key precursor which is used for a large variety of products actually is processed in many smaller factories. This is true in the case of substances used for the production of pharmaceuticals, for instance.

The need to include further processing in procedures designed to verify non-production again shows that a restrictive approach has to be adopted when determining key precursors. The proposal for limiting key precursors to such supertoxic lethal chemicals will minimize inspections of manufacturing companies because there are narrow qualitative and quantitative limits on the use of the substances in question for permitted purposes.

4. Inspection relating to the production of other lethal chemicals and precursors

As regards the monitoring of the non-manufacture of other lethal chemicals and precursors for the production of chemical weapons, various proposals have been submitted recommending an inspection procedure which would be restricted to the annual reporting of statistical data.

As these are mostly chemicals that are not only manufactured in large quantities but are also used for a variety of civilian purposes, the cost of ensuring a - as far as possible complete - record would be considerable. In order to achieve this, data on the manufactured, processed imported and exported quantities of every selected substance would have to be officially recorded. It is unknown to us whether and to what extent countries are at present able to maintain such comprehensive records or authorized under their respective data protection legislation to transfer said data to an international inspectorate.

Careful thought has yet to be given to the collection and evaluation of the data. The proposals submitted to date do not clearly indicate how the

international body can determine from the total data submitted whether a State has violated the convention. Moreover, the collection of comprehensive data must not lead to the disclosure of information about relationships with buyers in a manner and to an extent that might impair national economic interests.

IV. Summary

It is intended that the verification of non-production of chemical weapons should take the form of systematic international surveillance of specific sectors of the chemical industry, covering a list of selected substances to be annexed to a convention.

A convention banning chemical weapons will have to contain guidelines for determining the scope of such substances.

The guidelines for supertoxic lethal chemicals and their key precursors suggested in this paper limit the scope to such substances and specific precursors as would be listed in an annex to the convention.

The scope of the inspections must be such as to meet the verification requirements of the proposed convention, but also allow for the legitimate national economic interests of the chemical industry affected.

Surveillance should be limited to two measures, namely random on-site inspections based on the drawing of lots together with annual statistical reports on a scale yet to be agreed.

If the further processing of key precursors within the meaning of the above definition were to take place outside the production facility monitoring of the manufacture of these products would not be sufficient. In this case it would be necessary to extend inspections to domestic and foreign processors who have received them. The number of producers and manufacturing companies who would thus be subject to non-production inspections would be relatively small.

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