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REPORT OF THE CONFERENCE OF EXPERTS TO STUDY THE POSSIBILITY OF DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

Note by the Secretary-General

In accordance with the requests of the Governments of the Union of Soviet Socialist Republics and of the United States of America, the Secretary-General has the honour to circulate for the information of the Members of the General Assembly the attached report of the Conference of Experts to Study the Possibility of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests.[1/]

1/ The above report is being submitted to the members of the Security Council as document S/4091.

LETTER DATED 28 AUGUST 1958 FROM THE DEPUTY PERMANENT REPRESENTATIVE OF THE UNION OF SOVIET SOCIALIST REPUBLICS TO THE UNITED NATIONS ADDRESSED TO THE SECRETARY-GENERAL

28 August 1958

Pursuant to agreement reached between the Government of the Union of Soviet Socialist Republics and the Government of the United States of America in the course of an exchange of notes in April, May and June 1958, a conference of experts of both sides convened in Geneva from 1 July 1958 to 21 August 1958 to study the possibility of detecting violations of a possible agreement on the suspension of nuclear tests. The conference of experts concluded its work with the adoption of a report which the experts participating in the conference have submitted to their respective Governments. The Governments of the Union of Soviet Socialist Republics and the United States of America had agreed in their exchange of notes to keep the Security Council and the General Assembly informed of the work of the conference of experts through the intermediary of the Secretary-General. Accordingly, I have been instructed by my Government to submit to you the attached "Report of the Conference of Experts to Study the Possibility of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests" with the request that it be circulated to the Security Council and the General Assembly as a document of the United Nations.

(Signed) G. ARKADEV

Deputy Permanent Representative of the USSR to the United Nations

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LETTER DATED 28 AUGUST 1958 FROM THE DEPUTY PERMANENT REPRESENTATIVE OF THE UNITED STATES OF AMERICA TO THE UNITED NATIONS ADDRESSED TO THE SECRETARY-GENERAL

28 August 1958

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(Signed) James J. WADSWORTH
Deputy Permanent Representative of the United States to the United Nations

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REPORT OF THE CONFERENCE OF EXPERTS TO STUDY THE POSSIBILITY OF DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

21 August 1958

ORIGINAL: ENGLISH
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REPORT OF THE CONFERENCE OF EXPERTS TO STUDY THE POSSIBILITY OF DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

CONTENTS

I. INTRODUCTION

A. In accordance with an agreement reached as a result of an exchange of letters between the Chairman of the Council of Ministers of the Union of Soviet Socialist Republics, N. S. Khrushchev, and the President of the United States of America, Dwight D. Eisenhower, regarding the calling of a conference of experts to study the possibility of detecting violations of a possible agreement on the suspension of nuclear tests, there began on 1 July 1958, in Geneva, in the Palais des Nations, a conference of, on the one hand, experts from Western countries and, on the other hand, delegations of experts of the Union of Soviet Socialist Republics, the Polish People's Republic, the Czechoslovak Republic and the People's Republic of Romania.

B. The Secretary-General of the United Nations was represented at the Conference by his Personal Representative, Mr. T. G. Narayanan. Conference facilities and Secretariat services were provided by the United Nations. The Experts express their appreciation for the good offices of the Secretary-General and his Personal Representative, and for the services of the Secretariat staff attached to the Conference.

C. The agenda for the Conference, adopted on 4 July, included the following main questions:

1. Exchange of opinions on the problem of the various methods for detecting atomic explosions and on other general problems of the Conference deliberations.

2. Determination of a list of basic methods of systematic observations for phenomena indicative of an explosion.

3. A system for controlling the observance of an agreement on the cessation of nuclear tests.

4. Drawing up a report of experts to the governments of those countries represented at the Conference, with conclusions and suggestions regarding a system for controlling the observance of an agreement on the cessation of nuclear tests.

D. The Conference held 30 official sessions and completed its work on 21 August 1958. By prior agreement the Conference held its sessions in private.

E. The Conference of Experts considered the phenomena accompanying nuclear explosions set off under various conditions.

F. Some of these phenomena, namely the acoustic waves occurring when there are explosions in air and in water, the seismic oscillations that occur when there are explosions on the ground, under the ground, and under water, the radio pulses that are produced when there are explosions in the atmosphere, and the optical and gamma radiation when propagated over long distances, serve to indicate explosions and to estimate their time and place.

G. When nuclear explosions occur in the atmosphere the radioactive debris which is formed mixes in the atmosphere, and is dispersed over great distances. If a nuclear explosion is set off in the ocean or in the earth's crust, the radioactive debris will remain concentrated close to the site of the explosion for a considerable time.

H. The sensitivity of modern physical, chemical and geophysical methods of measurement makes it possible to detect nuclear explosions by the indications described above at considerable distances, as hereafter described. Thus it is known that explosions of high yield which are set off on the surface of the earth and in the lower part of the atmosphere can be detected without difficulty at points of the globe which are very remote from the site of the explosion. On the other hand, explosions which are of low yield (a few kilotons) can be detected with good reliability given the present state of observational techniques only if there is a specially set up control system such as that suggested in Section IV of this report.

I. A basic difficulty in detecting and identifying small explosions arises because many natural phenomena (earthquakes, thunder storms and others) give signals which are similar to those produced by explosions, or which by their presence hinder the detection of the signals sought.

J. The discrimination of the signals of natural events from signals of explosions is aided by a careful analysis of the recorded data, taking into account readings obtained at several points. Those remaining unidentified events which could be suspected as being nuclear explosions might be resolved by inspection of the site.

K. The Conference of Experts has considered the methods of detecting nuclear explosions by the acoustic, hydroacoustic and seismic oscillations which they produce in the air, water, or in the earth's crust, and, also the detection of explosions by the electromagnetic oscillations which are propagated from them, and by the radioactive debris that the explosions cause.

L. The Conference has examined the effectiveness and limitations of each of these methods for the detection of nuclear explosions and it has agreed that the combined use of the various methods considerably facilitates the detection and identification of nuclear explosions.

M. After examining the separate methods, the Conference examined the question of the technical equipment of the control system necessary to detect and identify nuclear explosions, and, after that, it passed to the question of the control system as a whole.

N. As a result of the examination of these questions the Conference reached the conclusion that it is technically feasible to set up, with the capabilities and limitations indicated in Section IV of this report, a workable and effective control system for the detection of violations of an agreement on the worldwide cessation of nuclear weapons tests.

O. In the present report information is given about the various methods of detection and identification of nuclear explosions, about the technical equipment of a control system and about a control system as a whole. Copies of the individual documents containing the conclusions adopted by the Conference on each of the questions mentioned are attached to the present report. Verbatim records and working documents in the working languages of the Conference will follow as soon as they are available for attachment to the report.

II. BASIC METHODS FOR DETECTION AND IDENTIFICATION OF NUCLEAR EXPLOSIONS

A. Conclusions as to the applicability of the Method of Recording Acoustic Waves for the Detection of Nuclear Explosions.

The Conference of Experts examined the process of propagation of the acoustic waves caused by nuclear explosions and the methods of recording these waves with the aim of determining the possibility of using them for detecting nuclear explosions.

1. When there are explosions in air, a strong air acoustic wave is formed which propagates over large distances. An indication of the amplitude of the air pressure wave is given by a formula which is approximately valid for a homogeneous atmosphere and according to which this amplitude is proportional to the cube root of the yield and inversely proportional to the distance. However, the amplitude of this acoustic wave is strongly dependent upon meteorological conditions and cannot be predicted accurately by a simple formula of such a kind. The observed amplitude in certain cases can be five times larger or smaller than that predicted by a formulation which includes only the energy release and the distance to detecting station.

2. Existing apparatus of special design can detect the air wave from a one kiloton explosion in the air above local background noise at relatively large distances.

The detection capability of a single station is strongly dependent upon the orientation of the propagation path to the station with respect to the upper winds. When the upper winds are mainly in one direction, a one kiloton explosion can be detected with a high degree of confidence downwind at a distance of 2,000 to 3,000 kilometres and upwind at a distance of 500 kilometres. When the upper winds are erratic and the average wind is small, such as frequently happens in the spring and fall, detection of a one kiloton explosion can be accomplished with a similar degree of confidence to a distance of approximately 1,300 kilometres independently of the direction. On the basis of the records from three stations, the location of the explosion can be determined with an accuracy of better than 100 kilometres.

3. The acoustic apparatus at control posts at the above distances from an explosion can detect explosions which occur between the surface and a height of [illegible] kilometres. A reasonable extrapolation of existing experience indicates that

for explosions taking place up to an altitude of about 50 kilometres there should not be a great change in the detectability of the acoustic wave. Whether a substantial acoustic wave will be generated at higher altitudes is not well known from direct experiment or from any theoretical considerations so far discussed. Deep underground and underwater explosions do not produce air waves sufficiently intense for detection purposes.

An underwater explosion in the oceans generates very strong underwater sound waves (hydroacoustic), which even in the case of small explosions can be detected at distances of about 10,000 kilometres.

4. Acoustic waves which resemble in certain cases the acoustic signals of nuclear explosions may be produced by natural events (primarily meteoric, volcanic or submarine disturbances). In such cases the identification of the event as natural or as a nuclear explosion must be based on a comparison of acoustic data with those obtained by aid of other methods.

5. It is noted that methods of recording of pressure waves may be further improved to increase the precision and the sensitivity, and to eliminate background noise and spurious signals.

B. Conclusions as to the Applicability of the Method of Using Radioactive Debris for Detecting and Subsequently Identifying Nuclear Explosions.

The Conference of Experts has studied the process of the dissemination of radioactive debris resulting from a nuclear explosion and has considered the collecti of samples of radioactive debris and its analysis as one of the methods for detecting and subsequently identifying nuclear explosions.

1. When an explosion occurs a considerable quantity of radioactive debris is produced. If the explosion is based on a fission reaction then this quantity amounts to 3×10^8 curies per 1 kt TNT equivalent of the energy of the explosion as of one hour after the reaction. Thermonuclear reactions will lead to the formati of Carbon 14, Tritium, and other radioactive substances which result from neutron irradiation and which, in principle, can also be used to detect an explosion.

2. When nuclear explosions occur between the earth's surface and a height of approximately ten kilometres the radioactive debris is thrown into the atmosphere where it is carried by winds to great distances. The concentration of this radioactive debris is greatly influenced by the vertical and horizontal distribution

of the wind in the troposphere and in the lower layers of the stratosphere. The concentration is also decreased as a consequence of washing out by rain and gravitational deposition.

3. The distribution by height of the radioactive debris carried in the atmosphe will depend in the first place on the energy of the explosion, on the conditions in which the explosion took place (i.e. on the earth, under the earth, or in the air) an on the meteorological conditions at the moment of explosion. In the case of low energy explosions in the air up to a height of approximately ten kilometres the radioactive debris will initially concentrate in a small volume below the tropopause. This debris will gradually get disseminated both horizontally and vertically in the troposphere and in the course of a period of from one to thirty days (depending on the turbulence of the atmosphere, the wind structure, and the dimensions of the particles which carry the radioactive substances) it can be detected close to the earth's surface, as also at various heights up to the tropopause.

4. The spreading of the cloud in the atmosphere is determined by many meteorological processes. As a result of the action of these processes the cloud is bound to reach a stage when it is mixed in a vertical direction and spread in a horizontal direction in such a way as to afford the most convenient conditions for taking samples.

Calculations and experimental data give ground for considering that this stage will be reached in the period between the fifth and twentieth day of the existence of the cloud. Before that period the cloud may be too small, both in its horizontal and its vertical extent. After thirty days have expired a considerable part of the radioactive debris will decay and a sample will constitute a lesser proportion of the natural or other background, thereby making more difficult the detection and identification of an explosion.

5. Existing radiochemical techniques make it possible to detect and identify fresh decay products in a sample of radioactive debris containing about 10^8 fissions. The time of origin of this fresh debris can be determined within five to ten per cent of its age if the sample contains about 10^{10} fissions and is not contaminated to any considerable extent by old fission products.

6. The taking of samples on the surface of the earth by a network of control posts makes it possible to carry out continual monitoring of the contamination of the air at many separate points by means of air filtration and also by collecting

radioactive fallout and fallout in rain. If control posts are disposed at distances of the order of 2,000 - 3,000 kilometres then an explosion with an energy of 1 kt set off in the troposphere (0 - 10 kilometres above the surface of the earth) will be detected with a high degree of reliability in the period of five to twenty days although the place of explosion cannot be exactly determined and although the time of explosion will be determined with some error. Calculation shows that with favourable meteorological conditions an explosion of even lesser energy can be detected in this way.

In the course of the period of time of from two to five days after an explosion of energy equivalent to 1 kt the collection of a sample of radioactive debris from the explosion which is suitable for analysis can be effected in the air by an aircraft if the area of the supposed location of the cloud is known approximately. The taking of such a sample will make it possible to establish approximately the point of the explosion by means of using meteorological data for back-tracking the trajectory of movement of the cloud.

7. Underground or underwater explosions set off at shallow depths and accompanied by the throwing up of earth or water can also be identified by the method of collecting radioactive samples although with lesser reliability than for explosions of the same energy in the troposphere.

8. The Conference of Experts considers that systematic measurements of radioactive substances in the air and also the collection of radioactive aerosols deposited on the ground and measurements of the radioactivity of precipitation can be successfully used for the detection of nuclear explosions and also, in many cases, for assessing certain parameters relating to them even in the absence of other indications.

The utilisation for a regular control service, as a method for detecting nuclear explosions, of the taking of samples of the air by aircraft over oceans can be used for detecting nuclear explosions. For this purpose use should be made of existing aircraft flights over the oceans which are carried out by various countries for the purposes of meteorological observations.

9. The Conference of Experts considers that the method of taking samples of radioactive debris can also be used successfully for subsequent investigation of the fact of a nuclear explosion in those cases when there are the appropriate indications from other methods.

For this purpose it is possible to use the detection of radioactive debris remaining at the point of the supposed explosion (on the earth's surface, under the earth, in the water) and also the determination of the presence of a radioactive cloud in the period between two and five days after a supposed explosion in the atmosphere in the area where the cloud is calculated to be by the time of investigation.

In such a case search for the radioactive cloud can be made on an aircraft having equipment for the taking of a sample of radioactive debris. To this end use should be made chiefly of the aircraft flights over the oceans made for the purposes of meteorological observations.

10. In some cases use can be made of aircraft flights over the territories of the USA, the USSR, the UK and other countries to collect air samples for the purpose of checking on data obtained by other methods of detection of nuclear explosions.

The Experts consider that to accomplish this task it would be quite sufficient to make use of the aircraft of the country being overflown and that in such cases it is sufficient that flights for the purpose specified should be made along routes laid down in advance. Representatives of the USSR, the USA, the UK or other States participating in the operation of the control system may be on board these aircraft in the capacity of observers.

11. The experts note that in the course of time the sensitivity and efficiency of the method of collecting radioactive debris will increase as a consequence of the atmosphere becoming cleared of the radioactive products it contains, and also as a result of the perfection of the techniques for collecting and analysing samples.

C. Conclusions as to the Applicability of the Method of Recording Seismic Waves for the Detection of Nuclear Explosions.

The Conference has considered the processes of propagation of seismic waves generated by nuclear explosions and the methods for recording these waves for the purpose of determining the possibility of using them for the detection of underground and underwater nuclear explosions.

1. When nuclear explosions occur under the ground or under the water, longitudinal, transverse and surface waves are formed and get propagated to great distances. The first longitudinal wave is the most important, both for detecting an explosion and for determining the place of the explosion, and also for distinguishing an earthquake from explosions. Transverse and surface waves also help to define the nature of a seismic perturbation.

2. Longitudinal seismic waves caused by underground nuclear explosions set off under conditions analogous to those in which the Rainier* shot occurred can be detected and the direction of first motion of the longitudinal wave can be determined at a distance of approximately 1,000 kilometres, and also at distances of approximatel 2,000-3,500 kilometres at sites which are considerably more quiet than the average for:

(a) explosions of the order of one kiloton recorded during periods of favourable noise conditions

(b) explosions of the order of five kilotons recorded during periods of unfavourable noise conditions.

It must be noted that all seismic stations situated at thousands of kilometres from one another cannot have an identically high or identically low level of background at one and the same time.

3. Conditions for detection and identification of underwater explosions set off in shallow water but at a sufficient depth, are considerably more favourable than conditions for detecting underground explosions.

4. Control posts carrying out seismic observations should be put at sites with a minimal level of microseismic background, such as are possible in internal continental regions. Such stations, when provided with arrays of seismographs, can

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* The underground nuclear explosion "Rainier" with an energy of 1.7 kilotons (Nevada) was set off in unfavourable conditions for transferring energy to the ground. However, even worse conditions of coupling are possible.

insure the obtaining of the data indicated above. However, at stations which are in unfavourable regions such as coastal and island regions the noise level will be higher than at quiet stations inside continents. In these cases for detection and determination of the sign of first motion the energy of the explosion must increase in the ratio of the power of 3/2 with respect to the increase of background level. This is in part compensated by the fact that quiet stations inside continents will register more powerful explosions at distances of from 2,000 to 3,500 kilometres. Bursts with an energy of 5 kilotons and more will be detected by quiet stations placed at the distances named.

5. The majority of earthquakes can be distinguished from explosions with a high degree of reliability if the direction of first motion of the longitudinal wave is clearly registered at 5 or more seismic stations on various bearings from the epicentre. Thus not less than 90 per cent of all earthquakes taking place in continents can be identified. The remaining 10 per cent or less of cases will require the analysis of additional seismograms where this is possible; and for this purpose use must also be made of the data of the existing network of seismic stations. If required, these supplementary stations should be further equipped with improved apparatus. In relatively aseismic areas it is sufficient merely to define the position of the epicentre. In this connection cases of detection of seismic events will be regarded as suspicious and will require further investigation with the help of other methods. For those cases which remain unidentified inspection of the region will be necessary.

In regions where the regular disposition of seismic stations in quiet conditions is not possible, the percentage of correct identification of earthquakes will be less.

With modern methods and making use of the data of several surrounding seismic stations the area within which an epicentre is localized can be assessed as approximately 100-200 square kilometres.

6. It is noted that the range and accuracy of recording and identifying underground nuclear explosions can be improved in the future by means of perfecting the methods of recording seismic waves, both by way of perfecting apparatus and also by way of perfecting the methods for differentiating an earthquake from explosions.

D. Conclusions on the Applicability of the Method of Recording of Radio Signals for the Detection of Nuclear Explosions.

The Conference of Experts considered the generation and propagation of radio pulses originating from a nuclear explosion and the methods of recording these signals in order to determine the possibility of using them for the detection of nuclear explosions.

1. In the case of a nuclear explosion in the atmosphere, there arises a powerful electromagnetic radiation (radio signal), caused by the gamma radiation accompanying the explosion. In the case of underground, underwater, or specially shielded explosions radio emissions are not expected which can be recorded at great distances by modern techniques.

When the explosion is carried out on or above the surface of the earth (water) and without specially constructed layers to absorb gamma rays, the energy and spectral distribution of the radio signal are such that its essential components are propagated over the whole terrestrial globe. The strength of the radio signal depends upon certain features of the construction of the bomb and on the altitude of the explosion. An explosion of 1 kiloton yield can be detected by means of radio signals at distances exceeding 6,000 km assuming that in the neighbourhood of the receiving station there is no high noise level from local thunderstorms or other sources.

By radio direction finding methods, it is possible to determine the azimuth of the signal source with an accuracy of about 2^{o}, i.e., about 30 km at a distance of 1,000 km. The time of production of the signal may be established with an accuracy of several milliseconds. The attainment of such accuracy depends on the choice of sufficiently flat location and on the absence of electrical interference at the receiving site.

2. Lightning flashes emit radio signals in the same frequency range and act as interference for the method of detection of a nuclear explosion by means of its radio signal.

Close to the source of radiation, the forms of radio signals from lightning and from nuclear explosions examined to date are quite different. However, at distances exceeding 1,000 kilometres, due to the distortion of the form of radio signals in the wave guide formed by the earth and the ionosphere, the form of radio signals from some individual lightning flashes is similar to the signal from nuclear explosions. The number of signals from lightning flashes recorded by apparatus without using special techniques of signal selection depends on the sensitivity of the apparatus and on the locality and can amount to from ten to several hundred signals per second. Existing techniques can be applied to exclude automatically the preponderant majority of signals from lightning. The distinction of the remaining signals due to atmospherics from those due to nuclear explosions requires the application of special methods of discrimination, including criteria on form of signal, spectral distribution and distance to source of radiation.

In the present state of the technique of the discrimination of signals in some individual cases the record of a signal cannot be identified either as coming from a nuclear explosion or from lightning.

3. The Conference of Experts recommends that further research should be carried out in order to understand more fully the physical properties of atmospherics involved in differentiating signals from nuclear explosions and atmospherics, by means of the development of the theory of this problem, the collection and systematization of data about atmospherics and the development of suitable automatic instruments. The Conference considers that there are good prospects for improvement of procedures of signal discrimination.

4. Theoretical considerations suggest that recording of radio signals can be used to detect nuclear explosions occurring at altitudes up to the order of 1,000 kilometres.

E. Conclusions on the Methods of Detection of Nuclear Explosions Carried out at High Altitude (More than 30 to 50 Kilometres) Above the Earth

The Conference of Experts has given theoretical consideration to the gamma radiation and neutrons resulting from a nuclear explosion and the conditions of recording them from earth satellites; and to optical phenomena and ionization of the air in the upper layers of the atmosphere in the case of a high altitude explosion (altitudes above 30-50 kilometres) and has arrived at the following conclusions:

1. A kiloton nuclear explosion produces at its source delayed gamma-rays from fission products, and prompt gamma-rays and neutrons. The number of prompt gamma-rays and neutrons depends upon the construction of the device and upon the materials surrounding it. The delayed gamma-rays are insignificantly affected by these factors. At a distance of 10^4 kilometres in vacuo, typical quantities of radiation from a one kiloton fission explosion are:

(a) Delayed gamma-rays

10^4 quanta/cm^2 during the first second

(b) prompt gamma rays*

10^2 quanta/cm^2

distributed over a time of about 10^{-7} sec.

(c) Neutrons

10^4 neutrons/cm^2

distributed over a time of a few seconds.

The cosmic background at the height at which earth satellites orbit is under study at the present time, attention being paid to the quantity, nature and energy of the particles; however, on the basis of preliminary data, it can be considered that the detection of an explosion from an earth satellite is possible, by means of registeri the gamma-rays accompanying the nuclear reaction, neglecting shielding, and also by means of registering the gamma rays of the fission products and the neutrons. If both prompt gamma rays and neutrons are registered, it is possible to get some idea of the distance to the explosion. The use of gamma-rays from a nuclear explosion will make it possible to detect the explosion in cosmic space at a distance of the order of hundreds of thousands of kilometres from the earth. Estimate of the maximum distance for the detection requires data concerning the magnitude of the cosmic radiation at the orbit of the earth satellite. If there is an explosion at a height of 30-50 km and above, and if the height at which the earth satellite orbits is some thousands of kilometres, one can neglect the absorption of gamma quanta in the upper layers of the atmosphere. The Conference of Experts considers that it is possible to use for the detection of nuclear explosions at high altitudes the registration of gamma-radiation and neutrons with properly instrumented earth satellites.

2. In the case of an explosion at a great height light will be emitted at the point of the explosion and there will be luminescence in the upper layers of the atmosphere under the action of X-rays and fast atoms from the materials in the device. Light phenomena may be detectable from the surface of the earth in clear weather at night with the help of simple apparatus; in day time with the help of

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* Special shielding of the exploding device can considerably reduce the gamma-radiation accompanying the reaction, but cannot reduce the radiation from fission products. However, such shielding involves increasing by several times the weight of the whole device.

more sensitive apparatus. In cloudy weather the detection of optical phenomena from stations on the earth's surface would probably be extremely difficult.

The radiation from a nuclear explosion creates in the upper layers of the atmosphere a region of increased ionization which is detectable by the absorption of cosmic radio-signals or by anomalies in the propagation of radio waves.

Our knowledge of the absorption of cosmic noise by ionospheric phenomena is not sufficient to determine the number of natural events similar to those resulting from a nuclear explosion.

The Conference of Experts considers that it is possible to use the recording of ionospheric phenomena, using appropriate radio techniques, and of optical phenomena for the detection of nuclear explosions at high altitudes.

3. The Conference of Experts has not considered the problem of the detection of nuclear explosions which might be conducted in cosmic space at distances of millions of kilometres from the earth.

F. The Conference has recommended the inclusion of the first four of these methods in the number of basic methods for detecting nuclear explosions by means of a network of control posts, and considers it possible to use several methods for detection of nuclear explosions at high altitudes as stated in IIE1 and IIE2.

III. CONCLUSIONS ON THE QUESTION OF THE TECHNICAL EQUIPMENT OF THE CONTROL SYSTEM FOR THE DETECTION AND IDENTIFICATION OF NUCLEAR EXPLOSIONS

The Conference of Experts has considered the questions related to the technical equipment of a control net intended to detect and identify nuclear explosions, and has come to the following conclusions:

1. The posts of the control net situated in continents should regularly be equipped with apparatus for the detection of explosions by the acoustic and seismic methods and also by the methods of recording radio signals and of collecting radioactive debris.

2. Certain posts situated on islands or near the shores of oceans should be equipped, in addition to the methods just mentioned, with apparatus for hydroacoustic detection of explosions.

3. Posts located on ships stationed or drifting within specified ocean areas should be equipped with apparatus for the detection of explosions by the method of collecting radioactive debris and by the hydroacoustic method. The method of recording radio signals and the acoustic method might also be used on ships if suitable equipment is developed, but the effectiveness of these two methods, particularly the acoustic one, will be considerably less than on land.

4. The apparatus installed at posts of the control network must be uniform and must satisfy the following basic technical requirements:

A. Seismic apparatus

The seismic apparatus of the control post should include:

(1) Approximately 10 short-period vertical seismographs dispersed over a distance of 1.5-3 kilometres and connected to the recording system by lines of cable. The seismographs should have a maximum magnification of the order of 10^6 at a frequency of 1 c.p.s. and a receiving band adequate to reproduce the characteristic form of the seismic signal;

(2) 2 horizontal seismographs with the parameters indicated in point (1);

(3) One three-component installation of long-period seismographs having a broad receiving band and a constant magnification of the order of $10^3 - 2 \times 10^3$ in the period range 1 - 10 seconds;

(4) One three-component installation of seismographs with a narrow receiving band and magnification of the order of 3×10^4 when T = 2 - 2.5 seconds;

(5) At certain posts one three-component installation of long-period seismographs with magnification of the order of $10^4 - 2 \times 10^4$ at periods of T = 25 seconds;

(6) Auxiliary equipment necessary in order to get precise records of the seismic signal; recording devices, chronometers, power supply units and apparatus for receiving automatic radio-signals giving correct time.

The seismic apparatus should be installed in places with a minimal level of micro-seismic background, away from industrial areas, and on outcrops of bedrock (where possible). The seismographs should be installed in suitable vaults.

The area required for installing the seismic apparatus should be about 3 x 3 kilometres.

B. Acoustic apparatus

(1) The infra-acoustic equipment for a control post should include not less than three sets of microbarographic units each of which should have: a system for averaging out turbulent noise, a pressure sensing unit, a transmission line and appropriate electronic amplifiers and automatic writing instruments;

(2) The sensitivity of the microbarographic stations must ensure recording of acoustic signals in the period range 0.5 - 40 seconds, with an amplitude of 0.1 dynes per cm^2;

(3) The pressure sensing units of the microbarographs should be disperse at about 10 kilometres from one another in order to determine the direction of arrival of the acoustic signal and the speed of propagation of the signal;

(4) The hydroacoustic apparatus for a post, which is recommended for use only in oceanic zones, should include several hydrophones placed in the main submarine sound channel.

The hydrophones should be connected with the recording station on the coast by cables. Recordings of the hydroacoustic signal should be made in several frequency sub-ranges, covering a general frequency range of from one cycle per second to several thousand cycles per second.

The infra-acoustic equipment operates best in areas of low surface winds and flat terrain covered with trees or shrubs.

C. Apparatus for recording a radio signal

The apparatus for recording a radio signal should consist of:

(1) A loop-shaped radio direction finder or a radio direction finder with vertical antennas dispersed 4-5 kilometres from one another, with a frequency range of 10-15 kilocycles per second which will detect signals as low as 2 millivolts per metre;

(2) A device for recording the form of the signal, the device to provide recording of the form of the radio-pulse in a frequency range 500 c.p.s. - 200 kilocycles per second when the intensity of the field is 10 millivolts per metre and more;

(3) An automatic selecting device based on separating out the characteristic electromagnetic signals accompanying nuclear explosions by their form, by their spectral density and by their amplitude and a device for analysing the signal spectrum that provides display of the spectral density of the signal in the frequency range 6 - 100 kilocycles per second. Although existing techniques exclude the preponderant majority of signals from lightning, further advantage will be taken of information from the acoustic, seismic or other basic methods of detection to aid in further discrimination between signals from nuclear explosions and from lightning flashes;

(4) The requisite measuring and auxiliary apparatus and also power-supply units and means for obtaining correct radio time signals.

The site on which the antennas and the electromagnetic recording apparatus are disposed should be on flat or rolling terrain with about 300 metres clear space around the antennas, and distant from sources of electrical interferences, power lines and communications lines.

D. Apparatus for collecting and analysing radioactive debris

The apparatus for collecting and analysing radioactive debris should include:

(1) A large filtering installation with a through-put capacity of 2×10^4 cubic metres of air over 10 - 24 hours, and which is used on a 24-hour basis;

(2) Equipment for collecting radioactive depositions -- a surface with about 100 square metres area should be used. During dry weather, the surface can be washed down to collect dry fallout;

(3) A laboratory for simple radiochemical analysis.

Apparatus should be located in open areas, preferably on high ground, with high precipitation frequency. Apparatus should not be located in cut-off valleys or near regions with high natural background.

E. Apparatus installed on aircraft for collecting radioactive debris and detection of a radioactive cloud.

(1) A filtering installation for aircraft should provide for the collection of the maximum quantity of the products of radioactive decay, the rate of filtering being about 3500 cubic metres an hour.

(2) The aircraft utilized for the collection of radioactive debris should have equipment for the comparatively fast determination of the presence of fresh radioactive debris.

(3) A small radiochemical laboratory will be located at each base for routine aircraft sampling flights.

Aircraft flights over ocean areas should be laid out as nearly as possible in approximately a north-south direction, and located near the sides of the major continents, as well as in the centre of oceans remote from continents.

5. All the apparatus of the control posts should be designed for reliable continuous operation.

6. Improved apparatus and techniques should be actively developed and expeditiously incorporated into the control system for the purpose of continuously improving the effectiveness for the detection and identification of nuclear explosions.

IV. CONCLUSIONS ON A CONTROL SYSTEM FOR DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

The Conference of Experts, having considered a control system for detecting violations of a possible agreement on the suspension of nuclear tests, has come to the conclusion that the methods for detecting nuclear explosions available at the present time, viz. the method of collecting samples of radioactive debris, the methods of recording seismic, acoustic, and hydroacoustic waves, and the radio-signal method, along with the use of on-site inspection of unidentified events which could be suspected of being nuclear explosions, make it possible to detect and identify nuclear explosions, including low yield explosions (1-5 kt). The Conference has therefore come to the conclusion that it is technically feasible to establish with the capabilities and limitations indicated below, a workable and effective control system to detect violations of an agreement on the worldwide suspension of nuclear weapons tests.

The Conference of Experts has come to the following conclusions regarding such a system:

1. The control system should be under the direction of an international control organ which would ensure the coordination of the activities of the control system in such a way that the system would satisfy the following technical requirements and perform the functions involved:

(a) The development, testing, and acceptance of the measuring apparatus and of the equipment, and stating the criteria for the siting of the control posts;

(b) Carrying out at the control posts and on aircraft, mentioned in items 3 and 5 of the present Conclusions, of continuous and effective observations for the phenomena which make it possible to detect nuclear explosions by the use of the methods recommended by the Conference;

(c) Reliable communication, with the aid of existing channels where they are suitable for this purpose, between the international control organ on the one hand and, on the other hand, the control posts and the bases from which the regular aircraft flights are carried out; communications and transportation should ensure the speedy transmission of the results of observations, of data (including samples), of reports, and of necessary supplies;

(d) Means of transport of personnel of the control posts in accordance with their duties and, so far as necessary, for the staff of the international control organ;

(e) Timely analysis and processing of the data from the observations of the control posts with the aim of speedily identifying events which could be suspected of being nuclear explosions, and in order to be able to report thereon in such manner as is considered by governments to be appropriate;

(f) Timely inspection of unidentified events which could be suspected of being nuclear explosions, in accordance with item 6 of the present Conclusions;

(g) Staffing of the control system (the network of control posts on land, on ships, and on aircraft, and also the staff of the international control organ) with qualified personnel having appropriate fields of specialization;

(h) Providing assistance in putting into effect a scientific research program, with the aim of raising the scientific standard of the system.

2. A network of control posts is characterized by three main parameters:

(a) The minimum yield adopted for the nuclear explosion or the natural events giving equivalent signals;

(b) The number of control posts;

(c) The probability of correct identification of natural events, particularly earthquakes.

The dependence between these parameters is such that with an increase in the yield of the explosion or the number of control posts the probability of detection and identification increases, and the number of unidentified events suspected of being a nuclear explosion decreases. On the other hand, for the identification of the increased number of unidentified events resulting from a smaller number of control posts it would be necessary to increase the number of on-site inspections or to make greater use of information coming from sources not subordinate to the international control organ or, if necessary, both.

The Conference considers that the problem of detecting and identifying underground explosions is one of the most difficult, and that, to a large extent, it determines the characteristics of the network of control posts.

3. The network of control posts would include from 160 to 170 land-based control posts (equipped in accordance with Section III of this report) and about 10 ships. Of these 160-170 control posts about 100-110 would be situated in

continents, 20 on large oceanic islands, and 40 on small oceanic islands; however, the exact number of control posts within the limits indicated above, can be determined only in the process of actually disposing them around the globe, taking into account the presence of noise at the sites at which they are located, and other circumstances.

The spacing between the control posts in continental aseismic areas would be about 1700 kilometres, and in seismic areas about 1000 kilometres. The spacing between the control posts in ocean areas would vary between 2000 and more than 3500 kilometres; the spacing between island control posts in seismic areas would be about 1000 kilometres. This would lead to the following approximate distribution of control posts over the globe (with a network including 110 continental posts):

North America - 24, Europe - 6, Asia - 37, Australia - 7, South America - 16, Africa - 16, Antarctica - 4; together with 60 control posts on islands and about 10 ships.

4. The tasks of the personnel of the control posts would include the ensuring of the normal functioning of apparatus, the preliminary processing of data received, and the forwarding of these data to the international control organ and to the government of the country on whose territory the control post is located in such a manner as may be considered appropriate by governments.

In order to carry out the tasks required one might need for each control post about 30 persons with various qualifications and fields of specialization, and also some persons for the auxiliary servicing staff.

5. In addition to the basic network described, air sampling would be accomplished by aircraft carrying out regular flights along north-south routes over the oceans along the peripheries of the Atlantic and Pacific Oceans, and also over areas of the oceans which are remote from surface control posts.

When it is necessary to investigate whether a radioactive cloud is present, in the case of detection of an unidentified event which could be suspected of being a nuclear explosion, special aircraft flights would be organized in order to collect samples of radioactive debris in accordance with Section II B 10.

6. When the control posts detect an event which cannot be identified by the international control organ and which could be suspected of being a nuclear explosion, the international control organ can send an inspection group to the

site of this event in order to determine whether a nuclear explosion had taken place or not. The group would be provided with equipment and apparatus appropriate to its task in each case. The inspection group would forward a report on the investigation it had carried out to the international control organ, and to the government of the country on the territory of which the investigation was made in such a manner as may be considered appropriate by governments.

7. The network of control posts disposed as described, together with the use of aircraft as described, would have the following effectiveness, subject to the qualifications discussed in items 8 and 9:

(a) Good probability of detecting and identifying nuclear explosions of yields down to about 1 kiloton, taking place on the surface of the earth and up to 10 kilometre altitude, and good probability of detecting, but not always of identifying, explosions taking place at altitudes from 10 to 50 kilometre. In these cases the independent methods enumerated in Sections II A, II B and II D would be used.

(b) Good probability of detecting nuclear explosions of 1 kiloton yield set off deep in the open ocean. In this case use would be made of the independent hydroacoustic and seismic methods described in Sections II A and II C.

The identification of underwater explosions can, in comparatively rare cases, be made more difficult by natural events which give similar hydroacoustic and seismic signals.

(c) Good probability of recording seismic signals from deep underground nuclear explosions in continents equivalent to 1 kiloton and above. In this case use would be made of the seismic method described in Section II C.

The problem of identifying deep underground explosions is considered in item 8.

8. Along with the observation of signals of possible underground explosions the control posts would record at the same time a considerable number of similar signals from natural earthquakes. Although, with the present state of knowledge and techniques, the network of control posts would be unable to distinguish the signals from underground explosions from those of some earthquakes, it could identify as being of natural origin about 90 per cent of the continental earthquakes, whose signals are equivalent to 5 kiloton, and a

small percentage of continental earthquakes equivalent to 1 kiloton*.

It has been estimated on the basis of existing data that the number of earthquakes which would be undistinguishable on the basis of their seismic signals from deep underground nuclear explosions of about 5 kiloton yield could be in continental areas from 20 to 100 a year. Those unidentified events which could be suspected of being nuclear explosions would be inspected as described in item 6.

The capability of the control system to identify underground nuclear explosions of 1-5 kiloton yield depends on:

(a) The small fraction of earthquakes that can be identified on the basis of data obtained from the control posts alone;

(b) The fraction of earthquakes that can be identified with the aid of supplementary data obtained from existing seismic stations; and

(c) The fraction of events still left unidentified which could be suspected of being nuclear explosions and for which the international control organ carries out inspection in accordance with item 6.

Although the control system would have great difficulty in obtaining positive identification of a carefully concealed deep underground nuclear explosion, there would always be a possibility of detection of such a violation by inspection.

The on-site inspection carried out by the international control organ in accordance with item 6 would be able to identify with good probability underwater nuclear explosions with a yield of 1 kiloton and above.

9. The Conference notes that in certain special cases the capability of detecting nuclear explosions would be reduced; for instance, when explosions are set off in those areas of the ocean where the number of control posts is small

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* The Conference notes that in order to increase the percentage of earthquakes of less than 5 kiloton yield which could be identified, it would be appropriate to supplement the data from the control posts by trustworthy data from the best existing seismic stations. The results of the observations of these seismic stations should, for this purpose, be made available to the international control organ, and the equipment of the seismic stations suitable for this purpose could be improved by using the best modern apparatus.

and the meteorological conditions are unfavorable; in the case of shallow underground explosions; when explosions are set off on islands in seismic regions; and in some other cases when the explosion is carefully concealed. In some cases it would be impossible to determine exactly the area in which a nuclear explosion that had been detected took place.

However, the Conference considers that whatever the precautionary measures adopted by a violator he could not be guaranteed against exposure, particularly if account is taken of the carrying out of inspection at the site of the suspected explosion.

10. The system described does not include specific means to detect and identify nuclear explosions at high altitudes (above 30-50 kilometres). The Conference has formulated its findings on the methods of detecting nuclear explosions set off at altitudes greater than 30-50 kilometres and has characterized these methods in Section II E.

11. The Conference of Experts recommends the control system described above for consideration by governments.

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The following experts participated as delegates at the Conference:

<u>Western Experts</u>

Dr. James B. Fisk
Dr. Robert F. Bacher
Sir John Cockcroft
Dr. Ernest O. Lawrence
Sir William Penney
Prof. Yves André Rocard
Dr. O.M. Solandt

<u>Delegations of:</u>

<u>Union of Soviet Socialist Republics</u>

E.K. Fedorov
N.N. Semenov
I.E. Tamm
M.A. Sadovski
O.I. Leipunski
I.P. Pasechnik
K.E. Gubkin
S.K. Tsarapkin

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19 August 1958

ANNEX I

CONCLUSIONS AS TO THE APPLICABILITY OF THE METHOD OF RECORDING ACOUSTIC WAVES FOR THE DETECTION OF NUCLEAR EXPLOSIONS

The Conference of Experts examined the process of propagation of the acoustic waves caused by nuclear explosions and the methods of recording these waves with the aim of determining the possibility of using them for detecting nuclear explosions.

The Conference came to the following conclusions:

1. When there are explosions in air, a strong air acoustic wave is formed which propagates over large distances. An indication of the amplitude of the air pressure wave is given by a formula which is approximately valid for a homogeneous atmosphere and according to which this amplitude is proportional to the cube root of the yield and inversely proportional to the distance. However, the amplitude of this acoustic wave is strongly dependent upon meteorological conditions and cannot be predicted accurately by a simple formula of such a kind. The observed amplitude in certain cases can be five times larger or smaller than that predicted by a formulation which includes only the energy release and the distance to detecting station.

2. Existing apparatus of special design can detect the air wave from a one kiloton explosion in the air above local background noise at relatively large distances.

The detection capability of a single station is strongly dependent upon the orientation of the propagation path to the station with respect to the upper winds. When the upper winds are mainly in one direction, a one kiloton explosion can be detected with a high degree of confidence downwind at a distance of 2,000 to 3,000 kilometres and upwind at a distance of 500 kilometres. When the upper winds are erratic and the average wind is small, such as frequently happens in the spring and fall, detection of a one kiloton explosion can be accomplished with a similar degree of confidence to a distance of approximately 1,300 kilometres independently of the direction. On the basis of the records from three stations, the location of the explosion can be determined with an accuracy of better than 100 kilometres.

3. The acoustic apparatus at control posts at the above distances from an explosion can detect explosions which occur between the surface and a height of 30 kilometres. A reasonable extrapolation of existing experience indicates that for explosions taking place up to an altitude of about 50 kilometres there should not be a great change in the detectability of the acoustic wave. Whether a substantial acoustic wave will be generated at higher altitudes is not well known from direct experiment or from any theoretical considerations so far discussed. Deep underground and underwater explosions do not produce air waves sufficiently intense for detection purposes.

An underwater explosion in the oceans generates very strong underwater sound waves (hydroacoustic), which even in the case of small explosions can be detected at distances of about 10,000 kilometres.

4. Acoustic waves which resemble in certain cases the acoustic signals of nuclear explosions may be produced by natural events (primarily meteoric, volcanic or submarine disturbances). In such cases the identification of the event as natural or as a nuclear explosion must be based on a comparison of acoustic data with those obtained by aid of other methods.

5. The Conference of Experts recommends the inclusion of methods for the recording of acoustic, air and hydro-acoustic waves in the list of the basic methods for the detection of nuclear explosions with the aid of a network of control posts. The Conference notes that methods of recording of pressure waves may be further improved to increase the precision and the sensitivity, and to eliminate background noise and spurious signals.

19 August 1958

ANNEX II

CONCLUSIONS AS TO THE APPLICABILITY OF THE METHOD OF USING RADIOACTIVE DEBRIS FOR DETECTING AND SUBSEQUENTLY IDENTIFYING NUCLEAR EXPLOSIONS

The Conference of Experts has studied the process of the dissemination of radioactive débris resulting from a nuclear explosion and has considered the collection of samples of radioactive débris and its analysis as one of the methods for detecting and subsequently identifying nuclear explosions. The Conference has come to the following conclusions:

1. When an explosion occurs a considerable quantity of radioactive débris is produced. If the explosion is based on a fission reaction then this quantity amounts to 3×10^{8} curies per 1 kT T.N.T. equivalent of the energy of the explosion as of one hour after the reaction. Thermonuclear reactions will lead to the formation of Carbon 14, Tritium, and other radioactive substances which result from neutron irradiation and which, in principle, can also be used to detect an explosion.

2. When nuclear explosions occur between the earth's surface and a height of approximately ten kilometres the radioactive débris is thrown into the atmosphere where it is carried by winds to great distances. The concentration of this radioactive débris is greatly influenced by the vertical and horizontal distribution of the wind in the troposphere and in the lower layers of the stratosphere. The concentration is also decreased as a consequence of washing out by rain and gravitational deposition.

3. The distribution by height of the radioactive débris carried in the atmosphere will depend in the first place on the energy of the explosion, on the conditions in which the explosion took place (i.e. on the earth, under the earth, or in the air) and on the meteorological conditions at the moment of explosion. In the case of low energy explosions in the air up to a height of approximately

* EXP/NUC/18/Rev.1 is in Russian only.

ten kilometres the radioactive débris will initially concentrate in a small volume below the tropopause. This débris will gradually get disseminated both horizontally and vertically in the troposphere and in the course of a period of from one to thirty days (depending on the turbulence of the atmosphere, the wind structure, and the dimensions of the particles which carry the radioactive substances) it can be detected close to the earth's surface, as also at various heights up to the tropopause.

4. The spreading of the cloud in the atmosphere is determined by many meteorological processes. As a result of the action of these processes the cloud is bound to reach a stage when it is mixed in a vertical direction and spread in a horizontal direction in such a way as to afford the most convenient conditions for taking samples.

Calculations and experimental data give ground for considering that this stage will be reached in the period between the fifth and twentieth day of the existence of the cloud. Before that period the cloud may be too small, both in its horizontal and its vertical extent. After thirty days have expired a considerable part of the radioactive débris will decay and a sample will constitute a lesser proportion of the natural or other background, thereby making more difficult the detection and identification of an explosion.

5. Existing radiochemical techniques make it possible to detect and identify fresh decay products in a sample of radioactive débris containing about 10^8 fissions. The time of origin of this fresh débris can be determined within five to ten per cent of its age if the sample contains about 10^{10} fissions and is not contaminated to any considerable extent by old fission products.

6. The taking of samples on the surface of the earth by a network of control posts makes it possible to carry out continual monitoring of the contamination of the air at many separate points by means of air filtration and also by collecting radioactive fallout and fallout in rain. If control posts are disposed at distances of the order of 2,000 - 3,000 kilometres then an explosion with an energy of 1 kT set off in the troposphere (0 - 10 kilometres above the surface of the earth) will be detected with a high degree of reliability in the period of five to twenty days although the place of explosion cannot be exactly determined and although the time of explosion will be determined with

some error. Calculation shows that with favourable meteorological conditions an explosion of even lesser energy can be detected in this way.

In the course of the period of time of from two to five days after an explosion of energy equivalent to 1 kT the collection of a sample of radioactive débris from the explosion which is suitable for analysis can be effected in the air by an aircraft if the area of the supposed location of the cloud is known approximately. The taking of such a sample will make it possible to establish approximately the point of the explosion by means of using meteorological data for back-tracking the trajectory of movement of the cloud.

7. Underground or underwater explosions set off at shallow depths and accompanied by the throwing up of earth or water can also be identified by the method of collecting radioactive samples although with lesser reliability than for explosions of the same energy in the troposphere.

8. The Conference of Experts considers that systematic measurements of radioactive substances in the air and also the collection of radioactive aerosols deposited on the ground and measurements of the radioactivity of precipitation can be successfully used for the detection of nuclear explosions and also, in many cases, for assessing certain parameters relating to them even in the absence of other indications, and it recommends the inclusion of the method of collecting samples of radioactive débris in the number of basic methods for detecting and identification of nuclear explosions by a network of control posts.

The Conference of Experts recommends the utilization for a regular control service, as a method for detecting nuclear explosions, of the taking of samples of the air by aircraft over oceans. For this purpose use should be made of existing aircraft flights over the oceans which are carried out by various countries for the purposes of meteorological observations.

9. The Conference of Experts considers that the method of taking samples of radioactive débris can also be used successfully for subsequent investigation of the fact of a nuclear explosion in those cases when there are appropriate indications from other methods.

For this purpose it is possible to use the detection of radioactive débris remaining at the point of the supposed explosion (on the earth's surface, under the earth, in the water) and also the determination of the presence of a radioactive cloud in the period between two and five days after a supposed explosion in the atmosphere in the area where the cloud is calculated to be by the time of investigation.

In such a case search for the radioactive cloud can be made on an aircraft having equipment for the taking of a sample of radioactive débris. To this end use should be made chiefly of the aircraft flights over the oceans made for the purposes of meteorological observations.

10. In some cases use can be made of aircraft flights over the territories of the USA, the USSR, the UK and other countries to collect air samples for the purpose of checking on data obtained by other methods of detection of nuclear explosions.

The Experts consider that to accomplish this task it would be quite sufficient to make use of the aircraft of the country being overflown and that in such cases it is sufficient that flights for the purpose specified should be made along routes laid down in advance. Representatives of the USSR, the USA, the UK or other States participating in the operation of the control system may be on board these aircraft in the capacity of observers.

11. The Experts note that in the course of time the sensitivity and efficiency of the method of collecting radioactive débris will increase, as a consequence of the atmosphere becoming cleared of the radioactive products it contains, as also as a result of the perfection of the techniques for collecting and analysing samples.

19 August 1958

ANNEX III

CONCLUSIONS AS TO THE APPLICABILITY OF THE METHOD OF RECORDING SEISMIC WAVES FOR THE DETECTION OF NUCLEAR EXPLOSIONS

The Conference has considered the processes of propagation of seismic waves generated by nuclear explosions and the methods for recording these waves for the purpose of determining the possibility of using them for the detection of underground and underwater nuclear explosions. The Conference has come to the following conclusions:

1. When nuclear explosions occur under the ground or under the water, longitudinal, transverse and surface waves are formed and get propagated to great distances. The first longitudinal wave is the most important, both for detecting an explosion and for determining the place of the explosion, and also for distinguishing an earthquake from explosions. Transverse and surface waves also help to define the nature of a seismic perturbation.

2. Longitudinal seismic waves caused by underground nuclear explosions set off under conditions analogous to those in which the Rainier** shot occurred can be detected and the direction of first motion of the longitudinal wave can be determined at a distance of approximately 1,000 kilometres, and also at distances of approximately 2,000-3,000 kilometres at sites which are considerably more quiet than the average for:

(a) Explosions of the order of one kiloton recorded during periods of favourable noise conditions

(b) Explosions of the order of five kilotons recorded during periods of unfavourable noise conditions.

It must be noted that all seismic stations situated at thousands of kilometres from one another cannot have an identically high or identically low level of background at one and the same time.

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* EXP/NUC/19/Rev.1 is in Russian only.

** The underground nuclear explosion "Rainier" with an energy of 1.7 kilotons (Nevada) was set off in unfavourable conditions for transferring energy to the ground. However, even worse conditions of coupling are possible.

3. Conditions for detection and identification of underwater explosions set off in shallow water but at a sufficient depth, are considerably more favourable than conditions for detecting underground explosions.

4. Control posts carrying out seismic observations should be put at sites with a minimal level of microseismic background, such as are possible in internal continental regions. Such stations, when provided with arrays of seismographs, can ensure the obtaining of the data indicated above. However, at stations which are in unfavourable regions such as coastal and island regions the noise level will be higher than at quiet stations inside continents. In these cases for detection and determination of the sign of first motion the energy of the explosion must increase in the ratio of the power of 3/2 with respect to the increase of background level. This is in part compensated by the fact that quiet stations inside continents will record more powerful explosions at distances of from 2,000 to 3,500 kilometres. Bursts with an energy of 5 kilotons and more will be detected by quiet stations placed at the distances named.

5. The majority of earthquakes can be distinguished from explosions with a high degree of reliability if the direction of first motion of the longitudinal wave is clearly recorded at 5 or more seismic stations on various bearings from the epicentre. Thus not less than 90 per cent of all earthquakes taking place in continents can be identified. The remaining 10 per cent or less of cases will require the analysis of additional seismograms where this is possible; and for this purpose use must also be made of the data of the existing network of seismic stations. If required, these supplementary stations should be further equipped with improved apparatus. In relatively aseismic areas it is sufficient merely to define the position of the epicentre. In this connexion cases of detection of seismic events will be regarded as suspicious and will require further investigation with the help of other methods. For those cases which remain unidentified inspection of the region will be necessary.

In regions where the regular disposition of seismic stations in quiet conditions is not possible, the percentage of correct identification of earthquakes will be less.

With modern methods and making use of the data of several surrounding seismic stations the area within which an epicentre is localized can be assessed as approximately 100-200 square kilometres.

6. The Conference of Experts recommends the inclusion of the nothod of recording seismic waves in the number of basic methods for detecting nuclear explosions with the help of a network of control posts. The Conference notes that the range and accuracy of recording and identifying underground nuclear explosions can be improved in the future by means of perfecting the methods of recording seismic waves, both by way of perfecting apparatus and also by way of perfecting the methods for differentiating an earthquake from explosions.

19 August 1958

ANNEX IV

CONCLUSIONS AS TO THE APPLICABILITY OF RECORDING OF RADIO SIGNALS FOR THE DETECTION OF NUCLEAR EXPLOSIONS

The Conference of Experts considered the generation and propagation of radio pulses originating from a nuclear explosion and the methods of recording these signals in order to determine the possibility of using them for the detection of nuclear explosions. The Conference came to the following conclusions:

1. In the case of a nuclear explosion in the atmosphere, there arises a powerful electromagentic radiation (radio signal), caused by the gamma radiation accompanying the explosion. In the case of underground, underwater, or specially shielded explosions radio emissions are not expected which can be recorded at great distances by modern techniques.

When the explosion is carried out on or above the surface of the earth (water) and without specially constructed layers to absorb gamma rays, the energy and spectral distribution of the radio signal are such that its essential components are propagated over the whole terrestrial globe. The strength of the radio signal depends upon certain features of the construction of the bomb and on the altitude of the explosion. An explosion of 1 kiloton yield can be detected by means of radio signals at distances exceeding 6,000 km assuming that in the neighbourhood of the receiving station there is no high noise level from local thunderstorms or other sources.

By radio direction finding methods, it is possible to determine the azimuth of the signal source with an accuracy of about 2°, i.e., about 30 km at a distance of 1,000 km. The time of production of the signal may be established with an accuracy of several milliseconds. The attainment of such accuracy depends on the choice of sufficiently flat location and on the absence of electrical interference at the receiving site.

2. Lightning flashes emit radio signals in the same frequency range and act as interference for the method of detection of a nuclear explosion by means of its radio signal.

Close to the source of radiation, the forms of radio signals from lightning and from nuclear explosions examined to date are quite different. However, at distances exceeding 1,000 kilometres, due to the distortion of the form of radio signals in the wave guide formed by the earth and the ionosphere, the form of radio signals from some individual lightning flashes is similar to the signal from nuclear explosions. The number of signals from lightning flashes recorded by apparatus without using special techniques of signal selection depends on the sensitivity of the apparatus and on the locality, and can amount to from ten to several hundred signals per second. Existing techniques can be applied to exclude automatically the preponderant majority of signals from lightning. The distinction of the remaining signals due to atmospherics from those due to nuclear explosions requires the application of special methods of discrimination, including criteria on form of signal, spectral distribution and distance to source of radiation.

In the present state of the technique of the discrimination of signals in some individual cases the record of a signal cannot be identified either as coming from a nuclear explosion or from lightning.

3. The Conference of Experts recommends that further research should be carried out in order to understand more fully the physical properties of atmospherics involved in differentiating signals from nuclear explosions and atmospherics, by means of the development of the theory of this problem, the collection and systematization of data about atmospherics and the development of suitable automatic instruments. The Conference considers that there are good prospects for improvement of procedures of signal discrimination.

4. Theoretical considerations suggest that recording of radio signals can be used to detect nuclear explosions occurring at altitudes up to the order of 1,000 kilometres.

5. The Conference of Experts recommends the inclusion of recording of radio signals among the methods of detecting nuclear explosions.

19 August 1958

ANNEX V

CONCLUSIONS AS TO THE METHODS OF DETECTION OF NUCLEAR EXPLOSIONS CARRIED OUT AT HIGH ALTITUDE (MORE THAN 30 TO 50 KM) ABOVE THE EARTH

The Conference of Experts has given theoretical consideration to the gamma radiation and neutrons resulting from a nuclear explosion and the conditions of recording them from earth satellites; and to optical phenomena and ionization of the air in the upper layers of the atmosphere in the case of a high altitude explosion (altitudes above 30 - 50 km) and has arrived at the following conclusions:

1. A kiloton nuclear explosion produces at its source delayed gamma-rays from fission products, and prompt gamma-rays and neutrons. The number of prompt gamma-rays and neutrons depends upon the construction of the device and upon the materials surrounding it. The delayed gamma-rays are insignificantly affected by these factors. At a distance of 10^4 kilometres in vacuo, typical quantities of radiation from a one kiloton fission explosion are:

(a) Delayed gamma-rays

10^4 quanta/cm^2 during the first second

(b) Prompt gamma-rays*

10^2 quanta/cm^2

distributed over a time of about 10^{-7} sec.

(c) Neutrons

10^4 neutrons/cm^2

distributed over a time of a few seconds.

The cosmic background at the height at which earth satellites orbit is under study at the present time, attention being paid to the quantity, nature and energy of the particles; however, on the basis of preliminary data, it can be considered that the detection of an explosion from an earth satellite is possible, by means of recording the gamma-rays accompanying the nuclear

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* Special shielding of the exploding device can considerably reduce the gamma-radiation accompanying the reaction, but cannot reduce the radiation from fission products. However, such shielding involves increasing by several times the weight of the whole device.

reaction, neglecting shielding, and also by means of recording the gamma rays of the fission products and the neutrons. If both prompt gamma rays and neutrons are recorded, it is possible to get some idea of the distance to the explosion. The use of gamma-rays from a nuclear explosion will make it possible to detect the explosion in cosmic space at a distance of the order of hundreds of thousands of kilometres from the earth. Estimate of the maximum distance for the detection requires data concerning the magnitude of the cosmic radiation at the orbit of the earth satellite. If there is an explosion at a height of 30 - 50 km and above, and if the height at which the earth satellite orbits is some thousands of kilometres, one can neglect the absorption of gamma quanta in the upper layers of the atmosphere. The Conference of Experts considers that it is possible to use for the detection of nuclear explosions at high altitudes the recording of gamma radiation and neutrons with properly instrumented earth satellites.

2. In the case of an explosion at a great height light will be emitted at the point of the explosion and there will be luminescence in the upper layers of the atmosphere under the action of X-rays and fast atoms from the materials in the device. Light phenomena may be detectable from the surface of the earth in clear weather at night with the help of simple apparatus; in day time with the help of more sensitive apparatus. In cloudy weather the detection of optical phenomena from stations on the earth's surface would probably be extremely difficult.

The radiation from a nuclear explosion creates in the upper layers of the atmosphere a region of increased ionization which is detectable by the absorption of cosmic radio-signals or by anomalies in the propagation of radio waves.

Our knowledge of the absorption of cosmic noise by ionospheric phenomena is not sufficient to determine the number of natural events similar to those resulting from a nuclear explosion.

The Conference of Experts considers that it is possible to use the recording of ionospheric phenomena, using appropriate radio techniques, and of optical phenomena for the detection of nuclear explosions at high altitudes.

3. The Conference of Experts has not considered the problem of the detection of nuclear explosions which might be conducted in cosmic space at distances of millions of kilometres from the earth.

19 August 1958

ANNEX VI

CONCLUSIONS AS TO THE QUESTION OF THE TECHNICAL EQUIPMENT OF THE CONTROL SYSTEM FOR THE DETECTION AND IDENTIFICATION OF NUCLEAR EXPLOSIONS

The Conference of Experts has considered the questions related to the technical equipment of a control net intended to detect and identify nuclear explosions.

The Conference has come to the following conclusions:

1. The posts of the control net situated in continents should regularly be equipped with apparatus for the detection of explosions by the acoustic and seismic methods and also by the methods of recording radio signals and of collecting radioactive debris.

2. Certain posts situated on islands or near the shores of oceans should be equipped, in addition to the methods just mentioned, with apparatus for hydroacoustic detection of explosions.

3. Posts located on ships stationed or drifting within specified ocean areas should be equipped with apparatus for the detection of explosions by the method of collecting radioactive debris and by the hydroacoustic method. The method of recording radio signals and the acoustic method might also be used on ships if suitable equipment is developed, but the effectiveness of these two methods, particularly the acoustic one, will be considerably less than on land.

4. The apparatus installed at posts of the control network must be uniform and must satisfy the following basic technical requirements:

A. Seismic apparatus

The seismic apparatus of the control post should include:

(1) Approximately 10 short-period vertical seismographs dispersed over a distance of 1.5 - 3 kilometres and connected to the recording system by lines of cable. The seismographs should have a maximum magnification of the order of 10^6 at a frequency of 1 c.p.s. and a receiving band adequate to reproduce the characteristic form of the seismic signal;

(2) 2 horizontal seismographs with the parameters indicated in point (

(3) One three-component installation of long-period seismographs having a broad receiving band and a constant magnification of the order of $10^3 - 2 \times 10^3$ in the period range 1 - 10 seconds;

(4) One three-component installation of seismographs with a narrow receiving band and magnification of the order of 3×10^4 when T = 2 - 2.5 seconds;

(5) At certain posts one three-component installation of long-period seismographs with magnification of the order of $10^4 - 2 \times 10^4$ at periods of T = 25 seconds;

(6) Auxiliary equipment necessary in order to get precise records of the seismic signal; recording devices, chronometers, power supply units and apparatus for receiving automatic radio-signals giving correct time.

The seismic apparatus should be installed in places with a minimal level of micro-seismic background, away from industrial areas, and on outcrops of bedrock (where possible). The seismographs should be installed in suitable vaults.

The area required for installing the seismic apparatus should be about 3 x 3 kilometres.

B. Acoustic apparatus

(1) The infra-acoustic equipment for a control post should include not less than three sets of microbarographic units each of which should have: a system for averaging out turbulent noise, a pressure sensing unit, a transmission line and appropriate electronic amplifiers and automatic writing instruments;

(2) The sensitivity of the microbarographic stations must ensure recording of acoustic signals in the period range 0.5 - 40 seconds, with an amplitude of 0.1 dynes per cm^2;

(3) The pressure sensing units of the microbarographs should be dispersed at about 10 kilometres from one another in order to determine the direction of arrival of the acoustic signal and the speed of propagation of the signal;

(4) The hydroacoustic apparatus for a post, which is recommended for use only in oceanic zones, should include several hydrophones placed in the main submarine sound channel.

The hydrophones should be connected with the recording station on the coast by cables. Recordings of the hydroacoustic signal should be made in several frequency sub-ranges, covering a general frequency range of from one cycle per second to several thousand cycles per second.

The infra-acoustic equipment operates best in areas of low surface winds and flat terrain covered with trees or shrubs.

C. Apparatus for recording a radio signal

The apparatus for recording a radio signal should consist of:

(1) A loop-shaped radio direction finder or a radio direction finder with vertical antennas dispersed 4 - 5 kilometres from one another, with a frequency range of 10 - 15 kilocycles per second which will detect signals as low as 2 millivolts per metre;

(2) A device for recording the form of the signal, the device to provide recording of the form of the radio-pulse in a frequency range 500 c.p.s. 200 kilocycles per second when the intensity of the field is 10 millivolts per metre and more;

(3) An automatic selecting device based on separating out the characteristic electromagnetic signals accompanying nuclear explosions by their form, by their spectral density and by their amplitude, and a device for analysing the signal spectrum that provides display of the spectral density of the signal in the frequency range 6 - 100 kilocycles per second. Although existing techniques exclude the preponderant majority of signals from lightning, further advantage will be taken of information from the acoustic, seismic or other basic methods of detection to aid in further discrimination between signals from nuclear explosions and from lightning flashes;

(4) The requisite measuring and auxiliary apparatus and also power-supply units and means for obtaining correct radio time signals.

The site on which the antennas and the electromagnetic recording apparatus are disposed should be on flat or rolling terrain with about 300 metres clear space around the antennas, and distant from sources of electrical interferences, power lines and communincations lines.

D. Apparatus for collecting and analysing radioactive débris

The apparatus for collecting and analysing radioactive débris should include:

(1) A large filtering installation with a through-put capacity of 2×10^4 cubic metres of air over 10 - 24 hours, and which is used on a 24-hour basis;

(2) Equipment for collecting radioactive depositions -- a surface with about 100 M^2 area should be used. During dry weather, the surface can be washed down to collect dry fallout;

(3) A laboratory for simple radiochemical analysis.

Apparatus should be located in open areas, preferably on high ground, with high precipitation frequency. Apparatus should not be located in cut-off valleys or near regions with high natural background.

E. Apparatus installed on aircraft for collecting radioactive débris and detection of a radioactive cloud

(1) A filtering installation for aircraft should provide for the collection of the maximum quantity of the products of radioactive decay, the rate of filtering being about 3500 cubic metres an hour.

(2) The aircraft utilized for the collection of radioactive débris should have equipment for the comparatively fast determination of the presence of fresh radioactive débris.

(3) A small radiochemical laboratory will be located at each base for routine aircraft sampling flights.

Aircraft flights over ocean areas should be laid out as nearly as possible in approximately a north-south direction, and located near the sides of the major continents, as well as in the centre of oceans remote from continents.

5. All the apparatus of the control posts should be designed for reliable continuous operation.

6. Improved apparatus and techniques should be actively developed and expeditiously incorporated into the control system for the purpose of continuously improving the effectiveness for the detection and identification of nuclear explosions.

19 August 1958

ANNEX VII

CONCLUSIONS ON A CONTROL SYSTEM FOR DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

The Conference of Experts, having considered a control system for detecting violations of a possible agreement on the suspension of nuclear tests, has come to the conclusion that the methods for detecting nuclear explosions available at the present time, viz. the method of collecting samples of radioactive débris, the methods of recording seismic, acoustic, and hydroacoustic waves, and the radio-signal method, along with the use of on-site inspection of unidentified events which could be suspected of being nuclear explosions, make it possible to detect and identify nuclear explosions, including low yield explosions (1-5 kiloton). The Conference has therefore come to the conclusion that it is technically feasible to establish, with the capabilities and limitations indicated below, a workable and effective control system to detect violations of an agreement on the worldwide suspension of nuclear weapons tests.

The Conference of Experts has come to the following conclusions regarding such a system:

1. The control system should be under the direction of an international control organ which would ensure the coordination of the activities of the control system in such a way that the system would satisfy the following technical requirements and perform the functions involved:

(a) The development, testing, and acceptance of the measuring apparatus and of the equipment, and stating the criteria for the siting, of the control posts;

(b) Carrying out at the control posts and on aircraft, mentioned in items 3 and 5 of the present Conclusions, of continuous and effective observations for the phenomena which make it possible to detect nuclear explosions by the use of the methods recommended by the Conference;

(c) Reliable communication, with the aid of existing channels where they are suitable for this purpose, between the international control organ on the one hand and, on the other hand, the control posts and the bases from which the regular aircraft flights are carried out; communications and transportation should ensure the speedy transmission of the results of observations, of data (including samples), of reports, and of necessary supplies;

(d) Means of transport of personnel of the control posts in accordance with their duties and, so far as necessary, for the staff of the international control organ;

(e) Timely analysis and processing of the data from the observations of the control posts with the aim of speedily identifying events which could be suspected of being nuclear explosions, and in order to be able to report thereon in such manner as is considered by governments to be appropriate;

(f) Timely inspection of unidentified events which could be suspected of being nuclear explosions, in accordance with item 6 of the present Conclusions;

(g) Staffing of the control system (the network of control posts on land, on ships, and on aircraft, and also the staff of the international control organ) with qualified personnel having appropriate fields of specialization;

(h) Providing assistance in putting into effect a scientific research programme, with the aim of raising the scientific standard of the system.

2. A network of control posts is characterized by three main parameters:

(a) The minimum yield adopted for the nuclear explosion or the natural events giving equivalent signals;

(b) The number of control posts;

(c) The probability of correct identification of natural events, particularly earthquakes.

The dependence between these parameters is such that with an increase in the yield of the explosion or the number of control posts the probability of detection and identification increases, and the number of unidentified events suspected of being a nuclear explosion decreases. On the other hand, for the identification of the increased number of unidentified events resulting from a smaller number of control posts it would be necessary to increase the number of on-site inspections or to make greater use of information coming from sources not subordinate to the international control organ or, if necessary, both.

The Conference considers that the problem of detecting and identifying underground explosions is one of the most difficult, and that, to a large extent, it determines the characteristics of the network of control posts.

3. The network of control posts would include from 160 to 170 land-based control posts (equipped in accordance with Conclusions EXP/NUC/23/Rev.1) and about 10 ships. Of these 160-170 control posts about 100-110 would be situated in continents, 20 on large oceanic islands, and 40 on small oceanic islands; however the exact number of control posts, within the limits indicated above, can be determined only in the process of actually disposing them around the globe, taking into account the presence of noise at the sites at which they are located, and other circumstances.

The spacing between the control posts in continental aseismic areas would be about 1,700 kilometres, and in seismic areas about 1,000 kilometres. The spacing between the control posts in ocean areas would vary between 2,000 and more than 3,500 kilometres; the spacing between island control posts in seismic areas would be about 1,000 kilometres. This would lead to the following approximate distribution of control posts over the globe (with a network including 110 continental posts): North America - 24, Europe - 6, Asia - 37, Australia - 7, South America - 16, Africa - 16, Antarctica - 4; together with 60 control posts on islands and about 10 ships.

4. The tasks of the personnel of the control posts would include the ensuring of the normal functioning of apparatus, the preliminary processing of data received, and the forwarding of these data to the international control organ and to the government of the country on whose territory the control post is located in such a manner as may be considered appropriate by governments.

In order to carry out the tasks required one might need for each control post about 30 persons with various qualifications and fields of specialization, and also some persons for the auxiliary servicing staff.

5. In addition to the basic network described, air sampling would be accomplished by aircraft carrying out regular flights along north-south routes over the oceans along the peripheries of the Atlantic and Pacific Oceans, and also over areas of the oceans which are remote from surface control posts.

When it is necessary to investigate whether a radioactive cloud is present, in the case of detection of an unidentified event which could be suspected of being a nuclear explosion, special aircraft flights would be organized in order to collect samples of radio-active débris in accordance with Conclusions EXP/NUC/18/Rev.2.

6. When the control posts detect an event which cannot be identified by the international control organ and which could be suspected of being a nuclear explosion, the international control organ can send an inspection group to the site of this event in order to determine whether a nuclear explosion had taken place or not. The group would be provided with equipment and apparatus appropriate to its task in each case. The inspection group would forward a report on the investigation it had carried out to the international control organ, and to the government of the country on the territory of which the investigation was made in such a manner as may be considered appropriate by governments.

7. The network of control posts disposed as described, together with the use of aircraft as described, would have the following effectiveness, subject to the qualifications discussed in items 8 and 9:

(a) Good probability of detecting and identifying nuclear explosions of yields down to about 1 kiloton, taking place on the surface of the earth and up to 10 kilometre altitude, and good probability of detecting, but not always of identifying, explosions taking place at altitudes from 10 to 50 kilometres. In these cases the independent methods enumerated in Conclusions EXP/NUC/7/Rev.1, EXP/NUC/18/Rev.2 and EXP/NUC/20/Rev.1 would be used;

(b) Good probability of detecting nuclear explosions of 1 kiloton yield set off deep in the open ocean. In this case use would be made of the independent hydroacoustic and seismic methods described in Conclusions EXP/NUC/7/Rev.1 and EXP/NUC/19/Rev.2.

The identification of underwater explosions can, in comparatively rare cases, be made more difficult by natural events which give similar hydroacoustic and seismic signals;

(c) Good probability of recording seismic signals from deep underground nuclear explosions in continents equivalent to 1 kiloton and above. In this case use would be made of the seismic method described in Conclusions EXP/NUC/19/Rev.2.

The problem of identifying deep underground explosions is considered in item 8.

8. Along with the observation of signals of possible underground explosions the control posts would record at the same time a considerable number of similar

and techniques, the network of control posts would be unable to distinguish the signals from underground explosions from those of some earthquakes, it could identify as being of natural origin about 90 per cent of the continental earthquakes, whose signals are equivalent to 5 kilotons, and a small percentage of continental earthquakes equivalent to 1 kiloton.*

It has been estimated on the basis of existing data that the number of earthquakes which would be undistinguishable on the basis of their seismic signals from deep underground nuclear explosions of about 5 kiloton yield could be in continental areas from 20 to 100 a year. Those unidentified events which could be suspected of being nuclear explosions would be inspected as described in item 6.

The capability of the control system to identify underground nuclear explosions of 1-5 kiloton yield depends on:

(a) The small fraction of earthquakes that can be identified on the basis of data obtained from the control posts alone;

(b) The fraction of earthquakes that can be identified with the aid of supplementary data obtained from existing seismic stations; and

(c) The fraction of events still left unidentified which could be suspected of being nuclear explosions and for which the international control organ carries out inspection in accordance with item 6.

Although the control system would have great difficulty in obtaining positive identification of a carefully concealed deep underground nuclear explosion, there would always be a possibility of detection of such a violation by inspection.

The on-site inspection carried out by the international control organ in accordance with item 6 would be able to identify with good probability underwater nuclear explosions with a yield of 1 kiloton and above.

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* The Conference notes that in order to increase the percentage of earthquakes of less than 5 kiloton yield which could be identified, it would be appropriate to supplement the data from the control posts by trustworthy data from the best existing seismic stations. The results of the observations of these seismic stations should, for this purpose, be made available to the international control organ, and the equipment of the seismic stations suitable for this purpose could be improved by using the best modern apparatus.

9. The Conference notes that in certain special cases the capability of detecting nuclear explosions would be reduced; for instance, when explosions are set off in those areas of the ocean where the number of control posts is small and the meteorological conditions are unfavourable; in the case of shallow underground explosions; when explosions are set off on islands in seismic regions; and in some other cases when the explosion is carefully concealed. In some cases it would be impossible to determine exactly the area in which a nuclear explosion that had been detected took place.

However, the Conference considers that, whatever the precautionary measures adopted by a violator, he could not be guaranteed against exposure, particularly if account is taken of the carrying out of inspection at the site of the suspected explosion.

10. The system described does not include specific means to detect and identify nuclear explosions at high altitudes (above 30-50 kilometres). The Conference has formulated its findings on the methods of detecting nuclear explosions set off at altitudes greater than 30-50 kilometres and has characterized these methods in Conclusions EXP/NUC/21/Rev.1.

11. The Conference of Experts recommends the control system described above for consideration by governments.