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INTELLIGENCE ANALYSIS OF THE GENEVA CONFERENCE TO STUDY THE METHODS OF DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

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CIA/SI 205–58
28 October 1958

CENTRAL INTELLIGENCE AGENCY

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PREFACE

This intelligence analysis of the Geneva Technical Conference on controls for a nuclear test moratorium has been prepared by Dr. Herbert Scoville, Jr., Assistant Director, Scientific Intelligence, CIA, and Chairman, Joint Atomic Energy Intelligence Committee. The material [redacted] has been prepared for publication in response to a number of informal queries received from within the intelligence community for a précis of his views on the Conference.

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FIGURE

INTELLIGENCE ANALYSIS OF THE GENEVA CONFERENCE TO STUDY THE METHODS OF DETECTING VIOLATIONS OF A POSSIBLE AGREEMENT ON THE SUSPENSION OF NUCLEAR TESTS

INTRODUCTION

The conference, to study methods of detecting violations of an agreement to suspend nuclear tests, took place at Geneva, Switzerland, during the period 1 July to 21 August 1958. The Western Delegation, which considered itself as a single team under the chairmanship of Dr. James B. Fisk, was composed of representatives from the United States, United Kingdom, France, and Canada. The Eastern Delegation, under the chairmanship of Dr. Fedorov, consisted of four separate delegations from the USSR, Czechoslovakia, Poland and Rumania. Although the Soviets made attempts to broaden the scope of the conference, the Western Delegation succeeded in maintaining the position that the conference was technical, not political, and that the decision on halting nuclear tests was not a matter for consideration. However, political overtones were present throughout the conference and agreement on technical matters frequently reflected political concessions.

In general, the Soviet approach was aimed at demonstrating the relative simplicity in detecting nuclear explosions under all types of conditions. The ranges at which detection could occur were exaggerated by their selection of idealized data or theories to support their position. The difficulties in discriminating between signals from explosions and natural events were also minimized by the Soviets. In general, the Eastern Delegates relied heavily on simplified theories with only minimal use of data to support those theories. The Western Delegation, on the other hand, relied heavily on the statistical approach using the wealth of data accumulated by the detection system over a period of years. The Western Delegation furthermore emphasized that many natural events gave signals similar to those from explosions and emphasized the requirement for discrimination in any detection system.

The conference approached the problem first by agreeing upon the detection methods which might be useful in such a system and then discussing and agreeing on the capabilities of each of these methods for detecting and identifying explosions under different types of environmental conditions. Both sides agreed on the following basic methods for use by this system, i.e., acoustic waves, radioactive debris, seismic waves and radio signals (electromagnetic). In the case of nuclear explosions at high altitudes (more than 30 to 50 kilometers), several additional methods were discussed and considered promising, but no specific recommendations for inclusion of these methods were made in view of the lack of experience in detecting explosions under these conditions.

After reaching agreed conclusions on these basic methods, discussions were held on the technical equipment which would be required by the control system. All of these methods were then consolidated into an overall world-wide control system for detecting violations of a nuclear test suspension. In addition to the basic technical methods of detection, this system included the principle of inspection of the location of events which could not be discriminated from nuclear explosions by scientific means alone .Finally, agreed conclusions were reached on the technical requirements for a control organization without consideration to the political problems involved therein. The agreed conclusions of the conference which have been published are included as annex A. A limited number of the transcripts are available in various Governmental offices and a complete transcript is expected to be published by the Department of State in the near future.

SUMMARY AND CONCLUSIONS

1. The Soviets evidenced a very strong motivation to obtain an agreed report without split position on the capabilities of a system to detect violations of a nuclear test suspension.

2. The Soviets made three major political concessions of great intelligence potential in agreeing to:

    a. The inclusion of a large number (between 15 and 20) of control posts in the Soviet Union.

    b. The principle of on-site inspection of appreciable numbers of unidentified events suspected of being nuclear explosions.

    c. Restricted overflight with international observers aboard.

3. The Soviets were apparently prepared to discuss most of the technical problems of detection, primarily on a theoretical basis, but were handicapped from a negotiating standpoint by the Western Delegation's versatile use of statistical and technical data.

4. The Soviets gave no evidence of intending to carry out concealed nuclear tests in the event of a suspension agreement.

DISCUSSION

SOVIET ATTITUDE TOWARD THE CONFERENCE

The most significant factor in the Soviet approach to this conference was their strong motivation to achieve an agreed report. This attitude became increasingly apparent as the conference progressed and was exemplified by a number of major political concessions. Just prior to the opening of the conference, serious question arose as to whether the Soviets would even attend, but when the seriousness of the Western Delegation was evidenced by the arrival of its members at Geneva, the Soviets in turn proceeded to Geneva and the conference began as originally scheduled on 1 July. However, the first two days were spent in political maneuvers in which the Soviets attempted to force the Western side to agree in advance that if the conference were a success, then nuclear testing should cease. The Western Delegation steadfastly refused to consider the problem of desirability of nuclear test cessation and insisted on limiting the discussions to the feasibility of detecting and identifying violations of a possible agreement on suspension of nuclear tests. The strong propaganda position of the Soviets, resulting from their unilateral announcement of test suspension while the U.S. was embarked on an extensive series of tests in the Pacific, made it difficult to keep the Western position from appearing unduly negative and might have provided the Soviets with considerable propaganda material had the conference broken down in the initial stages and the proceedings been published. However, after two fruitless days of such discussions, the Soviets requested a day's delay, obviously in order to obtain instructions, and then returned to the conference. Thereafter the discussions were almost entirely technical in nature, although strongly influenced by the political overtones.

The first real evidence of Soviet desire for agreement developed in the final stages of the discussion on the acoustic method of detecting nuclear explosions. The Soviets had presented data optimizing the ranges at which detection could be obtained and had presented to the conference draft conclusions embodying these ranges. In return, the Western Delegation had presented a statistical analysis which demonstrated that under practical conditions the ranges would be very much less than those proposed by the Soviets and presented alternative conclusions using much shorter ranges. After considerable discussion of the validity of these analyses and the various conclusions, the Soviets accepted the Western draft conclusions with only minor modifications. This agreement was the first real indication that the Soviets were prepared to accept scientific facts and did not desire split conclusions.

A more important example of this desire for agreement was demonstrated in the discussions which followed on the use of radiactive debris for detecting and identifying nuclear explosions. The outstanding Western success in collecting good early debris samples by aircraft and the difficulties experienced in reliably obtaining adequate samples by ground collection techniques led the West into proposing the use of aircraft in addition to ground sampling. The Eastern Delegation on the contrary strongly endorsed the thesis that ground sampling was reliable and adequate and that the use of aircraft was unnecessary, unduly complicated and expensive. This Soviet position was obviously based on their political sensitivity to the use of aircraft for intelligence purposes. Discussion on the relative merits of these two methods was protracted. The Western Delegation pressed the Soviets for data to support the reliability of the ground detection system, but the Soviets never succeeded in presenting data to substantiate this unsound technical position. Although private attempts were made to reassure the Soviets that our emphasis on aircraft was not based on desire for unrestricted overflight but rather on sound technical grounds, the Soviets were still extremely chary of the inclusion of any mention of aircraft as an important element of the system. The Soviets delayed achieving agreed conclusions on this subject for several weeks while apparently awaiting instructions from home, and the conference proceeded to other subjects. However, again the Soviets agreed to the inclusion of aircraft sampling as a basic element of the system even to the extent that overflight might be occasionally required. Admittedly, such overflight would be conducted by the aircraft of the nation involved, but the principle of having observers on board such aircraft was agreed to. Soviet agreement on this subject was again a strong proof that, provided the Western Delegation presented a sound technical position and held to this position, then the Soviets' desire for agreement would lead them to make major political concessions.

In the discussions on the use of seismic waves for detecting explosions, the Soviets again tended to theorize and to simplify the problem, particularly insofar as the ability to discriminate between seismic signals that emanate from explosions and those from earthquakes. In this case, the Soviet attitude may have been largely due to lack of scientific experience in such discrimination. The presentation of the U.S. data from the Rainier underground test was convincing to the Soviets and produced gradual acceptance by them of the difficulties involved in such discrimination. After the differences in scientific views had been ironed out, agreement was reached on the seismic method without raising any major political problems. The Eastern Delegation accepted these conclusions on the principle that at least five stations should obtain a strong seismic signal capable of determining the direction of the first motion in order to identify 90 percent of the earthquakes and eliminate them as possible nuclear explosions. This agreement later became a major factor in the discussions on the overall test detection system and the number of control posts required.

In the discussion that followed on the use of radio signals (electromagnetic method), the problem of discrimination between such signals from explosions and lightning flashes was again a dominant factor. The Soviets presented strong theoretical arguments for the potentialities for such discrimination using machine methods. However, no specific data were presented to support their proposal. In this particular discussion, the Soviets appeared to have been in a stronger technical position relative to the West than in any of the discussions on other methods. A major difference of opinion developed at this time, and continued almost to the end of the conference, on the feasibility of shielding out and thereby eliminating the electromagnetic signal from nuclear explosions. The U.S. representatives presented data to support the feasibility of such shielding but this was never fully accepted by the Soviets who wished to avoid any downgrading of the usefulness of this method. Unfortunately, the final record of the conference never completely clarified the technical facts on this point.

Since neither side gave any indication of experience at detecting tests at very high altitudes (greater than 30 to 50 kilometers), discussions on such test detection were primarily on a theoretical basis. (These discussions occurred prior to the U.S. ORANGE and TEAK shots at Johnson Island.) Both sides presented material on the possibilities of using gamma and neutron radiation, ionization phenomena, and optical methods. The Soviets pressed very strongly for the use of "sputniks" equipped with gamma and neutron detectors while the Western Delegation pressed for equal consideration of the use of ionization phenomena. The most violent session of the entire conference occurred during an informal meeting designed to iron out the final wording of the conclusions on these methods. The Soviets exhibited great sensitivity to the Western proposal to use radio techniques, i.e., passive radio telescopes or active systems, probably because of their fear of the intelligence potential of such systems. In view of the lack of experimental data in advance of the U.S. tests and the classification of U.S. theoretical calculations on the ionospheric phenomena, conclusions were finally agreed to which placed the use of gamma and neutron detectors in satellites in a slightly dominant position over the ionospheric phenomena, but neither method was recommended for specific inclusion in a system due to the technical uncertainties still existing.

Discussions on the equipment to be used by the detection system were almost entirely technical in nature and involved no serious disagreements. The Soviets for the first time raised the possibility of using ships as platforms for detection stations in ocean areas where suitable land masses were not available. The usefulness of ships for acoustic and electromagnetic detection was seriously questioned by the West and finally only included on a downgraded basis. For the land stations, it was agreed that all four basic systems, i.e., acoustic, seismic, electromagnetic and radioactive debris collection, would be included at every station. This collocation has been found difficult by the West but was strongly endorsed by the Soviets and is very likely their practice.

The major problem of the conference revolved around the integration of these various methods into a worldwide system capable of detecting tests under all possible conditions. At the Soviet insistence, the discussion on all the basic methods had been aimed at detection and identification of tests of yields of 1 kiloton (KT) or greater despite Western desires to include consideration of higher yields as well. Therefore, in designing the overall system, 1 KT was initially used as a basic parameter. The detection and identification of underground explosions was the dominant factor in determining the basic characteristics of the system of control posts.

The initial Western attempt at designing a system involved about 650 stations for a 1 KT worldwide system, while the Soviets proposed 100 stations. The Soviet proposal was obviously inadequate for discriminating between earthquakes of 1 KT energy equivalent and explosions since 5 stations would never obtain signals with clear first motions from such an event. The Eastern Delegation proposed the use of existing worldwide seismic stations as a supplement to the detection system, but the ease with which seismic records could be falsified and the signals from an explosion made to resemble those of an earthquake rendered this solution impractical. At this point, the Western Delegation proposed that a system be designed with capabilities of good discrimination of yields 5 KT and greater and the Eastern Delegation accepted this approach. Such a Western system would involve 160 to 170 stations while the Soviet designed system would involve 130. Not unexpectedly, the Soviets agreed to the Western 160 to 170 station system just prior to the conclusion of the conference. This Soviet acceptance of a worldwide system which would involve between 15 and 20 control posts in the USSR manned by about 30 persons was a second major political concession resulting from this conference.

Since at present it is technically impossible to identify a nuclear explosion by seismic means alone, inspection of the site of an unidentified event suspected of being a nuclear explosion is necessary in order to prove or disprove the existence of a concealed nuclear test. It was agreed that the 160 to 170 control post system would leave unidentified some 20 to 100 events per year of yields greater than 5 KT equivalent. Inspection would be required in such cases. Furthermore, if a system is to have any capability for yields of less than 5 KT, inspection on a random basis would be required in order to deter the conduct of lower yield tests. The Soviets early in the conference referred to the need for inspecting sites of suspected nuclear explosions but consistently deferred the inclusion of statements to this effect in any of the agreed conclusions. Finally, however, in the conclusions on the control system such inspection was agreed to. This acceptance of the principle of inspection was the third and perhaps most important political concession made by the Soviets at the conference in order to achieve an agreed report.

EVALUATION OF SOVIET INTENTIONS TO CARRY OUT CONCEALED NUCLEAR TESTS

Prior to the conference, many members of the U.S. Delegation believed that the Soviets were attempting to establish a situation in which U.S. nuclear testing would stop and the Soviets would continue weapons development by means of concealed tests. The conference gave no evidence to support this thesis and indeed led all Western representatives with whom this was discussed to change their views. While the Soviets fought strenuously on many points and attempted to minimize the difficulties in establishing an adequate test detection system, this approach appeared aimed entirely at avoiding politically sensitive situations such as large numbers of observers within the Soviet Union, overflight and free access to many locations behind the Iron Curtain. On all of these points, they ended up by making major concessions. Furthermore, the Soviets strongly pressed for a high sensitivity system, i.e., one capable of reliably detecting explosions as low as 1 KT. Had their objective been to design a system susceptible to evasion, they would have given much readier acceptance to the Western proposal to consider higher yield systems. In view of all the factors involved, it is believed that presently the Soviets have no intention of carrying out a concealed nuclear test in the event of a moratorium and that in accordance with present national estimates they would openly abrogate such an agreement before risking being caught in a violation. Furthermore, provided that the principle of inspection is adequately safeguarded in the political discussions and treaty, it is believed that the system as designed is adequate to deter any nation from conducting a concealed nuclear test. Without on-site inspections a system would not be capable of identifying a concealed, deep underground nuclear test of low yield.

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ANNEX A

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. **

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

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

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* United Nations General Assembly Report, A/3897, 28 August 1958, U.

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

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

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

Pursuant to agreement reached between the Government of the United States of America and the Government of the Union of Soviet Socialist Republics 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.

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

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

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 ampli-

tude 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. 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 collection 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 x 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 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 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 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 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 approximately 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.

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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.

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 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 postion 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°, 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 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.

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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.

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 registering 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 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 II E 1 and II E 2.

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 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 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 x 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 3,500 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 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 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 kilometres. 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 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.

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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.

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.

The following experts participated as delegates at the Conference:

Western Experts

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

Delegations of:

Union of Soviet Socialist Republics

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

Polish People's Republic

M. Miesowicz
L. Jurkiewicz
M. Blusztajn

Czechoslovak Republic

C. Simane
F. Behounek
A. Zatopek
Z. Trhlik

People's Republic of Romania

H. Hulubei

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.

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 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.

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.

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

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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.

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 method 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.

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 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°, 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.

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 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.

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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.

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 (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 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 communications 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 x 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 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 3,500 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.

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 in Annex VI) 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 radioactive débris in accordance with Conclusions in Annex II.

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 in Annexes I, II, and IV 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 in Annexes I and III.

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 in Annex III.

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 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;

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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.

(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 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 in Annex V.

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

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ANNEX B

EVALUATION OF EASTERN REPRESENTATIVES AT GENEVA TECHNICAL CONFERENCE

USSR SCIENTISTS

BALASHOV, Konstantin Ivanovich — Balashov participated only in the acoustic discussions and gave the impression to Western scientists that his primary interest was in the experimental and field aspects of this program. He seemed familiar with the details of the actual equipment used for this method and might be responsible for the operation of the acoustic net.

He did not associate much with Western scientists and it was not very easy to get an impression of his qualifications. He certainly did not give an impression of being particularly outstanding. However, he was very sincere in his attempt to learn whatever he could about interpretation of acoustic records. He said he had come to this program about five years ago.

BREKHOVSKIKH, Leonid Maksimovich — Brekhovskikh's primary scientific field is acoustics and radiowave propagation, and he was probably one of the best Soviet scientists at the conference. It is believed that he is not directly associated with the Soviet long-range detection program, but probably serves in some capacity as an adviser on the acoustic and electromagnetic phases. He seemed very sound theoretically and very much interested in a purely scientific approach. He stated that he is director of the Acoustical Institute of the Academy of Sciences of the USSR.

Brekhovskikh is a very amiable, honest individual, outgoing and seemed quite willing to carry on discussions with Western scientists. He speaks and understands English reasonably well.

FEDOROV, Yevgeniy Konstantinovich, Chairman of Eastern Delegation — Fedorov was by all means the dominant individual on the Eastern Delegation leading all discussions whether they were technical or semi-political. He was in complete command of the situation and even in specialized scientific fields the individual scientists followed very closely his direction. While he was undoubtedly getting political advice from Semen Konstantinovich Tsarapkin, Tsarapkin, himself, almost never spoke at the meetings and one got the impression that Tsarapkin was strictly an advisor and not directing Fedorov's activities.

On occasions, Nikolay Nikolayevich Semenov interjected himself into the discussions, but even though Fedorov obviously had to recognize Semenov's prestige as an Academician, he always kept himself in the directing role.

Fedorov demonstrated tremendous ability as a leader of a group and particularly as Chairman of the Delegation at the conference table. He showed an excellent ability to select out the key points of the problem and direct the discussion along lines most advantageous to the Soviet views. He is also adept at shifting the subject away from points sensitive to the Soviets. When backed into a corner, he becomes more vituperative, longwinded, and takes the offensive frequently on a personal basis against the position of the opposite delegation. He has a commanding presence at the conference table, thinks very rapidly and is very capable at presenting views on an ad hoc basis. While apparently reasonably sound on an overall scientific basis, he is nevertheless not averse to stretching scientific truths in order to establish his point. In many cases, he has twisted scientific facts or used them falsely in order to give the appearance of justifying the Soviet position. Overall he is an extremely capable individual, ruthless and a difficult adversary across a conference table.

There was no indication during the conference of Fedorov's connection with nuclear weapons development programs or with the Soviet long-range detection program. Undoubtedly in his position as a senior scientific administrator, his connections with the Soviet satellite program, and also his military associations, he is generally familiar with Soviet weapons development programs, but there is no evidence that he is directly responsible for any of these. He personally took the most active part in the scientific discussions on the radioactive debris method which is reasonable in light of his meteorological background, which was the key factor on this subject. However, his scientific knowledge of the field was not sufficiently great to indicate a very close association with the details. He evidenced no experience with the radiochemical aspects of this problem.

He can read English rather easily and I believe he can understand quite a good bit of spoken English, but has difficulty in composing his thoughts and speaking them in English.

GUBKIN, Konstantin Emelyanovich — Gubkin's primary field of interest was acoustics and he seemed quite familiar with the Soviet acoustic detection program. It is quite likely that he is responsible at least for the theoretical and analytical aspects of this, but he showed less familiarity with the experimental and instrumentation aspects. On several occasions, he discussed simplified hydrodynamic calculations which might indicate some possible connection with the weapons effects or perhaps even weapons development programs. He is apparently involved in classified research of some sort because of several rather transparent attempts on the part of him and his associates to avoid discussing the organization for which he works.

Gubkin is a young, enthusiastic and very competent scientist. On occasion, he appeared naive and allowed his enthusiasm to lead him to make comments which were not necessarily too sound. He is extremely friendly, showed willingness to talk to Western scientists and at social occasions his drinking increased his natural gay, good natured attitude. He speaks broken English and seemed interested in trying to expand his knowledge. On the other hand, it was somewhat difficult for him to understand unless one confined the conversation to very simple phrases.

KIRDIN, Gennady — Kirdin participated only in discussions on the diffusion of radioactive debris in the atmosphere. Privately, he stated that he had never applied these diffusion calculations to atmospheric conditions prior to the meeting. His connection with the long-range detection program is not clear, but possibly he is associated with the debris phases of the program at the Institute of Applied Geophysics. His one presentation did not show any particular evidence of outstanding competence.

LEIPUNSKI, Ovsei Ilich — Leipunski participated primarily in the discussion on high altitude and electromagnetic methods. His approach seemed to be primarily theoretical and gave no indication that he was directly connected with the Soviet long-range detection program. He did show some knowledge of weapons development, but not sufficiently to give any indication of whether he was presently connected with this program. His presentations were reasonably competent but did not demonstrate any outstanding scientific ability. He made one presentation on debris from thermonuclear explosions which had little, it any, scientific value and seemed aimed primarily at the propaganda aspects of dangers from nuclear weapons. His paper was a rehash of his published article on clean bombs.

Initially, he seemed to be somewhat pompous and impressed with himself, but over a period of time became more relaxed. He seemed a very determined individual who kept his mind rather narrowly on his objectives.

PASECHNIK, Ivan Petrovich — Pasechnik appeared to be the Soviet scientist in charge of the seismic detection program. His approaches to the problem seemed routine and straightforward and he did not evidence much imagination. He is probably directly responsible for all experimental programs in the seismic field. He showed some knowledge of the acoustic program and may have some responsibility in this work as well, particularly insofar as field instrumentation is concerned. It is possible that the Soviet acoustic program has been parasitic on their seismic program. Mention was made of collocation of acoustic and seismic stations and Pasechnik mentioned putting the simplified sylphon bellows device at seismic stations. It is possible that Pasechnik is responsible for the operation of these.

He appeared to be a fairly competent seismologist but definitely not in the top echelon scientifically. He seemed very positive in his attitudes and belligerent toward any possible criticism. His statements were frequently made for the purpose of supporting a view rather than achieving the best scientific answer. He speaks a little English but seemed to have to rely primarily on translation.

RIZNICHENKO, Yuriy Vladimirovich — Riznichenko is one of the better Soviet seismologists. He arrived only at the latest stages of the meeting after the discussions on seismic detection had raised a number of difficult scientific problems for the Soviets. He indicated that he was experienced in seismology of earthquakes, but had no practical experience in studying the seismic records from explosions. He approached the problem of differentiating between earthquakes and explosions on an idealized basis and did not seem cognizant of the very difficult practical problems in this field. It was unlikely that he is connected with the Soviet long-range detection program, but he was probably being called in as an adviser at the last moment. He advanced the erroneous theory that explosions do not produce shear waves. When he was shown the experimental Rainier data, he readily acknowledged his error.

SADOVSKI, Mikhail Aleksandrovich — Sadovski appeared to be the senior member of the group responsible for Soviet programs in the field of detection of explosions. It seems probable that his responsibility covers at least the geophysical aspects of the Soviet long-range detection program, that is, at least the acoustic and seismic methods and probably the electromagnetic method as well. He did not participate in any of the discussions on the subject of radioactive debris and it seems possible that this part of the Soviet program is administered separately from the strictly geophysical aspects. It seemed probable that supervision of the LRD program is his full-time duty although possibly he is a senior adviser, thoroughly familiar with all aspects. On one occasion, he indicated that his interests lay in analyzing results and planning programs and that he allowed younger scientists to actually conduct the experimental work.

Initially, Sadovski gave the impression of being gruff but over a period of time he became very friendly and associated quite freely with his opposite members on the Western Delegation. Western scientists found him easy to discuss scientific matters with and reasonable in his approach. He did not follow party lines in these discussions, but appeared to seek the best scientific solution. His scientific stature was sufficiently high to permit him to take independent positions and on one occasion to the amusement of the conferees he contradicted Academician Semenov publicly and stated that the Western delegates were correct and Semenov wrong. He gave the impression of being a reasonably competent scientist, but not brilliant. He reads a little English but relies almost completely on translation.

SEMENOV, Nikolay Nikolayevich — Semenov was the Eastern scientist at the conference with probably the greatest international reputation being an Academician and Nobel Prize winner. This scientific stature was not demonstrated by Semenov's activities at the conference. He appeared very narrow-minded and on many occasions missed the point of the discussions. These examples of obtuseness were probably not in many cases calculated in order to support a Soviet position, but were really a lack of comprehension, perhaps brought on by personal prejudice on his part. His approaches were frequently naive and his points were often pressed repeatedly despite the lack of scientific backing. He evidenced a most peculiar insistence on superiority of (even nonsensical) theory to experimental data. On at least one occasion, he pushed a given calculation to the point where the Western Delegation had to show up the falsity of his calculation. Despite these unsound viewpoints, he never was willing to admit any errors.

There was no evidence in his activities that he was directly involved in the detection program or the weapons development program. However, there is a possibility that he is an adviser in the latter or may have been involved sometime in the past. It is also possible that he may have been involved in the radiochemical aspect of the detection program but this subject was studiously avoided in any Soviet presentations.

Semenov gave the impression of being a very vain individual, proud of his established international scientific reputation. He gave little or no evidence of a true scientific approach and seemed completely engrossed in party line scientific thinking. He was cold and only showed any signs of warmth when his vanity was being catered to. Semenov took pride that Sadovski, Gubkin, and Brekhovskikh were his students.

TAMM, Igor — Tamm was probably the best true scientist in the Eastern Delegation. However, his field of theoretical physics was not particularly pertinent to the discussions of the conference. As a consequence, he participated almost not at all in the discussions of the conference. He was probably not a major factor in the Soviet delegation. His closest association seemed to be with Ovsei Ilich Leipunski and he showed his greatest interest during the discussions on methods of detecting tests at high altitudes. At the formal conferences he was practically ignored by Fedorov.

Tamm has an extremely warm and friendly personality. He is very outgoing and enthusiastic about everything in which he participates and has a tremendous fund of energy. He showed no hesitation in associating with members of the Western Delegation and indeed rather liked to talk English with them. He is very uninhibited and relaxed with people. He showed a considerable fondness for pretty girls. He has a tremendous enthusiasm for mountain climbing and is still extremely active despite his age.

USTYUMENKO, Aleksandr — Ustyumenko was primarily involved in the electromagnetic methods and is probably responsible for this phase of the Soviet long-range detection program. He seemed to have fairly general knowledge of all types of instrumentation which might be used in the long-range detection program and took over in the absence of Sadovski the detailed discussions on the conclusions for the instrumentation. He was very active in defending the electromagnetic method against Western criticism, but did not demonstrate outstanding scientific ability in this respect. In fact, he had a tendency to overlook facts in order to support his viewpoint. On one occasion in the formal conference, he deliberately mis-stated the Western position even though in a private discussion the matter had been previously explained to him. He gave rather convincing evidence that the Soviet electromagnetic program has been pushed very hard, even including some type of automatic discriminator. This is the one example where they may be more advanced in techniques of detection than we are and Ustyumenko displayed confidence in this.

CZECHOSLOVAKIAN SCIENTISTS

Czechoslovakia was represented by three scientists, Cesmir Simane, Frantisek Behounek, and Alois Zatopek. Of all the satellite scientists, Simane seemed to be the closest to the Soviets and was allowed to make statements on subjects which involved serious Soviet interests. However, his presentations did not demonstrate any outstanding scientific ability. Throughout the conference, he gave the impression that he was trying to ingratiate himself with the Soviets.

Simane does not appear to be an outstanding scientist and probably holds his senior position in the Czech Atomic Energy Program as a result of Soviet support. He seems very impressed with his own abilities and pleased with himself every time he makes a statement. He has a nervous habit of giggling or laughing after almost every sentence which reinforces this impression.

Behounek took almost no active role at all. He was called on to give one stereotyped talk on radioactive fall-out which did not contribute to the conference work at all and was aimed for its propaganda value. He gave no indication of any scientific competence.

Zatopek seemed to be a reasonably sound, conventional seismologist. He showed no familiarity with the long-range detection program, but did make presentations relative to general problems involved in conventional seismology or earthquakes. He was a friendly individual with no apparent political connections. He was very unhappy at his not being allowed to come to the U.S. and not being allowed to travel outside of the Iron Curtain. I believe he would like to cultivate his connections with Western scientists.

POLISH SCIENTISTS

Neither Marian Mensowitch nor Leopold Iurkewitch, the two Polish delegates, gave any evidence of being directly connected with or knowledgeable of the long-range detection program. Mensowitch is believed to be a very competent physicist and appeared bored by having to participate in the interminable conference sessions. The presentations which both Mensowitch and Iurkewitch made were purely the formal type, probably prepared by the Soviets and did not contribute to the working of the conference. Both Poles seemed very eager to be friendly with Western scientists and would like to avoid giving the appearance of close association with the Soviet unit. It is believed that they were responsible for leaking, on at least one occasion, information to a Western journalist.

RUMANIAN SCIENTIST

Horia Hulubei did not participate in any of the scientific discussions at the meeting and apparently had no knowledge of the subjects of the conference. His presentations were obviously prepared by the Soviets and did not contribute to the work of the conference. He was a very friendly individual and associated at several occasions, particularly with the French delegates, probably because of his long past associations in France. He appeared to be somewhat of a lonely individual and was not seen with the other Eastern delegates outside the meetings.

Figure 1. Eastern delegation at the Geneva Technical Conference