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The story behind the East-West experts' exploration of nuclear test detection methods and their agreed conclusions, pregnant with latent purport for intelligence.

POLICING A NUCLEAR TEST BAN

Herbert Scoville, Jr.

The East-West conference on methods of detecting violations of any international agreement to suspend nuclear tests, held in Geneva from 1 July to 21 August 1958, was in effect, as might be expected, a USSR-West conference. The Western delegation, a single team with members from the United States, the United Kingdom, France, and Canada, faced four separate delegations from the USSR, Czechoslovakia, Poland, and Rumania; but the Satellite delegates only presented papers apparently prepared by the Soviets and made no substantive contribution to the discussions. The Soviets attempted to broaden the scope of the conference to include agreement to stop testing nuclear explosions, but the Western delegations succeeded in maintaining the position that the agenda was technical, not political, and that the decision on halting tests was not a matter for consideration. Nevertheless the technical discussions were colored throughout with political overtones, and several of the technical agreements reflect Soviet political concessions.

The conference agreed first on technical methods which might be useful in a detection system and on the capabilities of each of these methods for identifying explosions under different types of conditions. Both sides agreed on the use of acoustic waves, radioactive debris, seismic waves, and electromagnetic (radio) signals to detect and identify surface, atmospheric, underground, and underwater explosions. For explosions at very high altitudes (30 to 50 kilometers and above) several additional methods of detection were discussed and considered promising, but none were specifically recommended for inclusion in the system, since experience with explosions at such heights is lacking.

After reaching agreement on these basic methods the conferees agreed on the technical equipment which would be required to put them to effective use, and then consolidated them into a recommended worldwide control system for policing a nuclear test suspension, specifying in some detail its technical requirements and disposition. This recommended system includes a provision for inspection of locations in which the control network has detected possibly natural phenomena that it has not been able to distinguish from nuclear explosion effects.

The Agreements

Acoustic Waves. It was agreed that with a sufficient distribution of listening posts the acoustic wave method would be effective in measuring and locating one-kiloton explosions in the air up to an altitude of 30 or perhaps 50 kilometers. The acoustic method is not applicable to underground explosions, but under the oceans even small explosions can be detected by hydroacoustic methods to distances of 10,000 kilometers. The instruments which record these air or water pressure waves can be expected to improve in precision and sensitivity, but they will not always be able to distinguish between acoustic signals from nuclear explosions and those from some infrequent natural events such as meteor falls, volcanic eruptions, and submarine disturbances. Acoustic detection must therefore be supplemented by other methods, even to identify explosions which do not occur underground.

Radioactive Debris. It was agreed that analysis of radioactive debris is effective in identifying and locating either fission or fusion explosions, and three methods of collecting samples were recommended. Control posts 2000 to 3000 kilometers apart on the ground would detect one-kiloton explosions in the air up to 10 kilometers high by sampling fallout 5 to 20 days afterwards, but would be subject to considerable error in determining the place of explosion and to some error in determining the time. If the approximate location of a suspected explosion is known, however, an aircraft can collect samples two to five days afterwards for a close determination of time and place. Shallow underground and underwater explosions are also susceptible of detection, with less reliability, by these means. Finally, inspection teams might collect samples from suspected sites of underground or underwater explosions, as well as surface tests, and examine them for radioactive debris.

It was recommended that ground posts and existing aircraft flights over international waters be used for routine sampling, and that when other detection data indicated a need for air samples over the territory of any nation, that nation's aircraft should carry observers from other nations in the control organization in sampling flights over predetermined routes. The debris method would become increasingly effective with prolongation of a period free of nuclear explosions and with the perfection of sampling and analysis techniques.

Seismic Waves. Seismic waves provide the only method for initial detection of nuclear explosions underground or under waters not linked hydroacoustically with the oceans; and seismic wave detection is less discriminating than other methods. It was agreed that, given a sufficient distribution of control posts and ordinary seismic stations, 90 percent or more of five-kiloton seismic disturbances would be identified and located within a radius of about five miles, but the identification of one-kiloton explosions would require unusually favorable conditions and unusually quiet seismic stations within a range of 1000 kilometers. It was noted that the range and discrimination of this method would probably be increased with improvements in apparatus and technique, but seismic disturbances not positively identified as natural earthquakes would probably still give rise to the greatest number of demands for regional inspections—perhaps as many as 100 per year, even if limited to magnitudes of five kilotons or greater.

Radio Signals. The radio signal caused by gamma radiation from an explosion on or above the earth's surface provides a detection means of great range and accuracy, but there is difficulty at ranges greater than 1000 kilometers in distinguishing it from the electromagnetic emissions of lightning flashes. The conference made reference also to a possibility that the radio signal might be deliberately altered or eliminated through shielding the explosion against gamma emissions. It recommended further research to improve discrimination and develop automatic equipment for this purpose.

High-Altitude Explosions. The detection of explosions at an altitude of 30 to 50 kilometers and above was discussed on a theoretical basis, but no recommendations were made. Three methods were considered. The registration by earth satellite instruments of gamma radiation and neutrons would detect nuclear explosions hundreds of thousands of kilometers from the earth, but there are difficulties in the possibility of shielding the explosion and in uncertainties about background cosmic radiation. Light from the explosion itself and the luminescence of affected upper layers of the atmosphere would be revealing, but would not be observable from the ground in cloudy weather. Such an explosion would also create a measurable increase in the ionization of the upper atmosphere, but an unknown number of natural phenomena might produce similar effects. The detection of explosions millions of kilometers from the earth was not discussed.

The Control Network. The conference set up recommended specifications for acoustic, hydroacoustic, seismic, and electromagnetic detection equipment, and for apparatus to collect samples of radioactive debris both on the ground and in aircraft. It recommended that all ground posts of the control net be equipped for all methods of detection, except that hydroacoustic equipment would be needed only on islands and ocean shores and in ships. Ships could also collect debris samples and might use the radio and aeroacoustic methods with reduced effectiveness, but could not use the seismic method.

The number of control posts required was determined largely on the basis of the needs of the seismic method, since the discrimination of underground explosions presents the greatest problems. 160 to 170 land-based posts were recommended, 60 of them on islands, along with about 10 ships. The posts should be as close together as 1000 kilometers in seismic areas, but could be diffused to distances of about 1700 kilometers in aseismic continental areas and of 2000 to 3500 kilometers in aseismic ocean areas. It was suggested that each post might require a personnel complement of about 30 specialists plus supporting staff.

It was agreed that this system would effectively discourage violations of a nuclear test suspension: it would provide good probability of detecting and identifying all explosions down to one kiloton except those set off underground. It would detect underground one-kiloton explosions but would be able to distinguish only a small percentage of them from earthquakes. Without on-site inspection, in fact, it would be impossible to positively identify deep underground nuclear explosions even of high yields, since they could always be claimed to have been earthquakes. If, however, the ten percent or less of five-kiloton disturbances not identified as earthquakes and a number of lesser events taken at random were subject to site inspection, a violator could not feel secure against exposure no mattter what precautions he took.

The identification by inspection of deep underground nuclear explosions would still be very difficult. All the radioactive debris would remain confined in a small volume deep underground, and surface evidence might be very difficult to obtain. An inspection team would have to survey the suspect area indicated by the seismic signals for signs betraying the conduct of a test—recently used mine shafts or tunnels, excavations, logistic support for tests, or instrumentation. This task would of course be easier in completely deserted areas than in inhabited ones where signs of human activity would not be so suspicious. Finally, when suspicion of a concealed explosion was very high and the location closely determined, it might be necessary to drill many hundred feet for a sample of the radioactive material in order to prove a violation.

The Soviet Attitude

These agreements were not achieved in smooth harmony, in spite of an increasingly evident Soviet desire to avoid split conclusions. Just before the opening of the conference there was question 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 also came and the conference began as scheduled. Then the first two days were spent in political maneuvers, with the Soviets attempting to force the Western side to agree in advance that if the conference were a success nuclear testing should cease. The USSR's strong propaganda position resulting from its unilateral announcement of test suspension while the United States was engaged in an extensive series of tests made it difficult to keep the Western insistence on a purely technical conference from appearing too negative: Soviet propaganda could have exploited a breakdown of the conference in the initial stages and its published proceedings to considerable advantage. Finally, in the face of Western firmness, the Soviets requested a day's delay, obviously to obtain instructions, and then acceded to the Western position. Thereafter the discussions were almost entirely technical in nature, though shaped in some respects to take account of political factors.

In general, the Soviets attempted to make detection appear easy, while the Western delegates pointed out the practical difficulties in detecting and identifying nuclear explosions. Discrimination of natural events from possible explosions was usually simplified by the Eastern group. The U.S. representatives generally relied on the statistical use of experimental data, while the Soviets drew upon simplified theories. On one occasion, Semenov, a Soviet Nobel prize winner, amused the Western scientists by saying that the experimental evidence must have been faulty since it conflicted with his theories.

Specific evidence of Soviet desire for agreement developed toward the end of the discussion of the first of the methods for detecting nuclear explosions, that using acoustic waves. The Soviets had presented theoretical data optimizing the ranges at which explosions could be detected by this method and had proposed draft conclusions citing these ranges. Overnight three Western scientists prepared a statistical analysis, using data from more than 200 experimental observations of nuclear tests, which demonstrated that under practical conditions the ranges would be very much shorter than those given by the Soviets. The West proposed conclusions citing these short ranges. After considerable discussion of the validity of the analyses and their conclusions, the Soviets accepted the Western draft with only minor modifications. This accommodation was the first real indication that they were prepared to accept scientific facts at variance with their position in order to reach agreed conclusions.

A Major Concession

A more important demonstration of Soviet desire for agreement occurred in the discussions which followed on the use of radioactive debris for detecting and identifying nuclear explosions. Outstanding success in collecting good early debris samples by aircraft and difficulties experienced in obtaining reliable samples by ground collection techniques had led the West to propose the use of aircraft in addition to ground sampling. The Eastern delegations, on the other hand, strongly held that ground sampling was adequate and reliable, and that the use of aircraft was unnecessary, unduly complicated, and expensive. This position was obviously based on Soviet political sensitivity to the use of aircraft for intelligence purposes. Discussion on the relative merits of the two methods was protracted. Although the Western delegation pressed for data to support the reliability of the ground detection system, the Soviets never succeeded in substantiating their unsound technical position. Private attempts were made to reassure them that our emphasis on aircraft was not based on desire for unrestricted overflight but rather on sound technical grounds, but they remained extremely chary of the inclusion of any mention of aircraft as an important element of the system.

The Soviets delayed agreement to any conclusions on this subject for several weeks, apparently awaiting instructions from home, and the conference proceeded to other subjects. Finally, however, they again acceded, agreeing to the inclusion of aircraft sampling as a basic element of the system and even to the provision that overflight of national territory might occasionally be required. Such overflights, to be sure, would be made by the aircraft of the nation involved, but they would have observers from other nations on board. This first major political concession was strong proof that if the Western delegation presented a sound technical position and held to it, the desire for agreement would lead the Soviets to give way.

In the discussions on the use of seismic waves for detecting explosions, the Soviets again tended to theorize and to simplify the problem, particularly with respect to discriminating between the seismic signals from explosions and those from earthquakes. In this case, the Soviet attitude may have been due largely to lack of scientific experience in such discrimination. The presentation of the U.S. data on the Ranier underground test in September 1957 was convincing to them and won their gradual recognition of the difficulties involved. After the differences in scientific views had been ironed out, agreement was reached on the seismic method without the raising of any major political problems. The Eastern delegations accepted the Western conclusions which stipulated that, in order to identify 90 percent of the earthquakes and eliminate them as possible nuclear explosions, at least five stations should be so disposed with respect to any seismic disturbance as to obtain a strong signal capable of determining the direction of the first motion. This agreement later became a major factor in the discussions on the over-all detection system and the number of control posts required.

Next came discussions on the electromagnetic method, where the problem of discrimination between radio signals from explosions and those from lightning flashes was a dominant factor. The Soviets presented strong theoretical arguments for reliable discrimination with the use of machine methods, but no specific data to support their theory. In this discussion, however, they appeared to be in a stronger technical position relative to the West than in any of the others.

Technical Disagreements

A major difference of opinion developed at this time, and continued almost to the end of the conference, on the possibility of shielding out gamma radiation and thereby eliminating the electromagnetic signal from nuclear explosions. In the course of the discussion one of the U.S. scientists referred to success in shielding out the electromagnetic signals in a shallow underground explosion. When quizzed by the Soviets on how much earth was above the explosion the scientist had to admit the explosion occurred 75 feet underground. This amused the Soviets to no end; and although later experimental data were presented to demonstrate that even explosions on a tower could be shielded, they never fully accepted the feasibility of shielding, and tended to ridicule the Western position. Unfortunately the final record of the conference does not completely clarify the technical facts on this subject. This was a good example of how care must be used in selecting evidence to present at a meeting of this sort.

Since neither side gave any indication of experience in detecting tests at altitudes greater than 30 kilometers—this was before the U.S. ORANGE and TEAK shots at Johnson Island—high-altitude detection was discussed largely on a theoretical basis. Both sides presented material on the possibility 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 urged equal consideration of the use of ionization phenomena.

The most violent session of the entire conference occurred during an informal meeting arranged to iron out the final wording of the conclusions on these methods. This meeting, which had been intended to last for only a few minutes, started at ten o'clock on a Saturday morning, broke up for lunch at four PM, and finally continued until after eight in the evening, with both sides refusing to make any concessions. The Soviets exhibited great sensitivity to the Western proposal to use radio techniques, either passive radiotelescopes or active systems, probably out of fear of their intelligence potential. No agreement was reached that day, and over the weekend the Western delegation decided not to press further for its views. Instead it agreed that the conclusions would give some preference to satellite detection over ionospheric phenomena, but would specifically recommend neither for the detection system because of the lack of experimental data. When the chairman of the Western delegation made this concession at the opening of the following session, Fedorov, chairman of the Soviet delegation, was taken aback. He said plaintively that the Soviets had spent all day Sunday preparing technical papers to refute the Western position. He was almost unhappy that the West had conceded since it prevented his delegation from presenting these studies. Furthermore, in consequence of their wasted effort, the Soviets were unprepared to proceed to the next item on the agenda.

Discussions on the equipment to be used by the detection system were almost entirely technical in nature and involved no serious disagreements. The Soviets now 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 in an informal session it was agreed that use of these methods on shipboard would not be included in the conference conclusions. When these conclusions were taken up for ratification, Fedorov apparently had not been briefed that this item had been eliminated from the text, and the conclusions were ratified without further discussion. Later, just after Fedorov had unjustly chastised the Western delegation for not adhering to previously agreed conclusions on some other matter, the subject of shipboard detection again arose and Fedorov referred to these methods as an essential ingredient of the system. When it was called to his attention that he had just previously agreed to their elimination, he was considerably embarrassed.

The final text of the conclusions restored a qualified mention of the aeroacoustic and electromagnetic methods on shipboard. On land, it was agreed, all four basic systems—acoustic, seismic, electromagnetic and radioactive debris collection—would be used at every station. This collocation, found difficult by the West, was strongly endorsed by the Soviets and is very likely their practice.

More Political Concessions

The major problem of the conference was the integration of these various methods into a worldwide system capable of detecting tests under all possible conditions. At Soviet insistence, the discussion on all the basic methods had been keyed to small-yield test explosions, down to one kiloton, despite Western desires to include consideration of systems reliable only for higher yields. In designing the over-all system, therefore, the conference initially used the one-kiloton yield as a basic parameter.

The detection and identification of underground explosions was the dominant factor in determining the number and disposition of the control posts. The initial Western attempt at designing a system came up with about 650 stations for one-kiloton worldwide control, as against 100 proposed by the Soviets. The Soviet proposal was obviously inadequate for discriminating between one-kiloton underground explosions and earthquakes of equivalent energy, since five of the 100 stations would never obtain clear signals of first motions from such an event. The Eastern delegation then proposed the use of existing 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 suggested that a system be designed with capabilities of good discrimination for yields of five kilotons and greater, and the Eastern delegations accepted this approach. By Western criteria such a system required 160 to 170 stations, while in the Soviet design it would have 130. Not unexpectedly, the Soviets agreed to the Western figures just prior to the conclusion of the conference. This acceptance of a system which would involve between 15 and 20 control posts in the USSR, each manned by 30 or more persons, constituted a second major Soviet political concession at the conference.

Since at present it is not always technically possible 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 occurrence of a concealed nuclear test. The 160–170 control post system would leave unidentified some 20 to 100 events per year of energies equivalent to five-kiloton yields or greater, and it is clear that inspection would be required in such cases. Furthermore, if the system is to have any capability for yields of less than five kilotons, inspection of suspected sites of lower-yield tests on a random basis would be required as a deterrent to violations at this level. 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, they agreed to such inspection. This acceptance of the principle of inspection was the third and perhaps most important political concession made by the Soviets in order to achieve an agreed report.

Soviet Intentions

Before the conference, many members of the U.S. delegation believed that the Soviets were attempting to establish a situation in which they could continue weapons development by means of concealed tests and at the same time inhibit nuclear testing in the West. The conference yielded no evidence to support this thesis; in fact it had led all Western representatives with whom the subject was discussed to change their views. The Soviets fought strenuously on many points and attempted to minimize the difficulties inherent in establishing an adequate test detection system, but these efforts appeared aimed entirely at avoiding politically sensitive arrangements such as large numbers of observers, overflight, and free access to locations within the Soviet Union. On all of these points, they ended up by making major concessions.

Furthermore, the Soviets strongly pressed for a high-sensitivity system, one capable of reliably detecting explosions as low as one kiloton. Had their objective been to design a system susceptible of evasion, they would have given much readier acceptance to the Western proposal to consider higher-yield systems. In view of all these considerations, I believe that the USSR has no present intention of carrying out a concealed nuclear test in the event of a moratorium, and that it would openly abrogate such an agreement before risking being caught in a violation. Moreover, if the principle of inspection is adequately safeguarded in political discussions and in the terms of a suspension treaty, the system as designed is adequate to deter any nation from conducting a concealed nuclear test, at least with a yield greater than one kiloton. Without on-site inspections such a system would not be capable of preventing deep underground nuclear tests of even moderate yields.