~~CONFIDENTIAL~~

THE PRESIDENT'S SCIENCE ADVISORY COMMITTEE

EXECUTIVE OFFICE BUILDING

WASHINGTON 25, D. C.

January 12, 1959

MEMORANDUM FOR The Honorable Christian A. Herter
The Honorable John A. McCone
The Honorable Donald A. Quarles
The Honorable Allen W. Dulles
The Honorable Gordon Gray
The Honorable George Allen

SUBJECT: First Report of the Panel on Seismic Improvement

Attached for your information is the first report of a special Ad Hoc Panel on Seismic Improvement. This is the panel which I proposed at the meeting of the group called together by Secretary Herter on December 30, 1958 to discuss the implications of the new data on underground tests from Hardtack II.

The Panel which prepared the report was made up of the following individuals:

Victor Hugo Benioff, Professor of Seismology, California Institute of Technology

Hans A. Bethe, Professor of Physics, Cornell University

John Gerrard, Director, Data Systems and Earth Science Research, Texas Instruments, Inc.

David Tressel Griggs, Professor of Geophysics, Institute of Geophysics, University of California at Los Angeles

Jack H. Hamilton, Chief Engineer, The Geotechnical Corporation

Julius Paul Molnar, President Sandia Corporation

Jack E. Oliver, Seismologist, Lamont Geological Observatory, Columbia University

~~CONFIDENTIAL~~

Frank Press, Director, Seismological Laboratory, Division of the Geological Sciences, California Institute of Technology

Carl F. Romney, U. S. Air Force

Kenneth Street, Jr., Deputy Director, Livermore Laboratory

John W. Tukey, Professor of Mathematics, Princeton University

Lloyd V. Berkner, President, Associated Universities, Inc. (Chairman)

In brief, the panel concludes that there are four possible methods within the present state-of-the-art which might substantially improve the capabilities of the Geneva system.

With this report available, a next step would be for [redacted] to prepare a quantitative analysis of the effect of these four approaches on the capabilities of the Geneva system. 25X1

The individual members of the panel are continuing to study in greater detail the various seismic techniques described in this report, and in early February the panel will meet again to formulate further recommendations for a research program designed to evaluate the specific proposals, and to advance the state-of-the-art in relevant areas of seismology.

For your information, I also include a separate memorandum prepared by the panel concerning the value of a nuclear control system to geophysical research.

The President has requested me to obtain any comments you may have on the main report and to consolidate them with those received from other interested departments and agencies. These comments should be in the hands of this office not later than the close of business Friday, January 16, 1959. Pending the President's further consideration of the matter the panel report and memoranda are both classified and privileged.

The President has asked that staffing be held to the highest possible level.

J. R. Killian, Jr.

~~CONFIDENTIAL~~

January 7, 1959

REPORT OF THE PANEL ON SEISMIC IMPROVEMENT

1. The Panel on Seismic Improvement (PSI), appointed by the Chairman of the President's Science Advisory Committee, met in Washington on January 6 and 7, 1959, to review measures whereby it "would be reasonably feasible within the present state of seismic technology to improve the capabilities of the system recommended by the Geneva Conference of Experts to detect and to identify seismic events as either earthquakes or explosions without increasing the number of manned control posts in the system."

2. The capabilities of the Geneva system with regard to underground tests have recently been reevaluated by another Panel on the basis of new data from the underground tests at HARDTACK II. The PSI did not attempt to evaluate further the specific capability of the Geneva System. The proposals recommended herein would increase the estimated capabilities of the GenevaSystem. It is noted that the data on nuclear shots used in these estimates was from Rainier and HARDTACK II and thus has all the limitations of that small sample of nuclear test conditions. The PSI has not concerned itself with the possible seismic effects of nuclear tests under different conditions or the possibilities of concealment by decoupling or other techniques.

3. The Geneva System of seismic identification places principal reliance on the assessment of a single phenomenon, i.e. the direction of displacement of the first arrival of the P-wave in a specified network of seismic instruments. The PSI considered a variety of seismic phenomena and techniques which have been suggested to increase the capability of the Geneva System without adding manned control posts, including:

(a) Evaluation of the first motion of the P-wave with aid of approximate inverse transfer functions.

(b) Surface wave phenomena using long-period instruments.

(c) Unmanned, auxiliary seismic stations.

(d) Larger arrays of seismometers at manned control posts.

(e) Improvements from increased knowledge of the transmission properties of the earth by experience in operation of the system.

(f) After shocks as a diagnostic feature.

(g) Radiation asymmetry at the source.

(h) Use of computers in data analysis.

(i) Use of higher frequency seismic signals.

(j) Detectors on ocean bottom.

(k) Detectors in deep hole.

(l) Diagnostic possibilities of microseisms.

(m) Focal depth of disturbances.

5. On the basis of its review of the above techniques, the PSI believes that the following four promising approaches are within the present limits of technology and should be considered:

(a) Analysis of long-period surface waves. The capability of the Geneva System for the identification as earthquakes of seismic events equivalent to 5 kilotons or larger by the analysis of long-period surface waves is conservatively estimated at 25% and may be much larger.

(b) Network of unmanned auxiliary seismic stations. A triangular network of such unmanned stations is suggested, spaced 170 km apart between the stations of the 1000 km grid proposed in Geneva for the seismic regions of the world. If this network were installed and effectively operated, it would very greatly increase the capability of the Geneva system for identifying as earthquakes those seismic events occurring in interior areas and corresponding in energy to underground tests equivalent to one kiloton or larger.

(c) Larger arrays of seismometers at manned control posts. It is reasonably certain that the replacement of 10 distributed seismometers per control post as recommended by the Geneva Conference of Experts with arrays of approximately 100 distributed seismometers would increase the signal to noise ratio by a factor of from 1.5 to 2.5. This would substantially increase the capability of the system to identify small seismic events as natural earthquakes.

(d) Detectors in deep holes. A detection method which employs a seismometer in a hole at a depth of several thousand feet is being investigated at the present time. The method offers possibilities for improving the detectability of small signals by a factor of the order of ten, provided that the technological problems of operating instruments

at the required depths can be solved. The results to date are incomplete but encouraging. If the factor of ten can in fact be achieved, it would drastically increase the capability of the system to identify small seismic events as natural earthquakes. More definitive results are expected by mid 1959.

The proposals (a), (b), and (c), above, are discussed more fully in the appendix attached.

6. The PSI invites attention to the fact that detection of aftershocks by specially and immediately implaced seismometers can be used by an inspection party as an aid in establishing that an unidentified seismic event was in fact a natural earthquake.

7. The PSI believes that seismic research has not in the past been supported as strongly as many other areas of science. Vigorous research in seismology is certain to produce many improvements that cannot now be predicted. It is certain that this would lead to an improvement in detection capabilities. The PSI will shortly report its detailed recommendations concerning research in seismology.

8. The PSI urges that sample detection networks be established without delay as representative systems to disclose operational and design problems and provide a firmer basis for the assessment of detection capabilities.

9. The Geneva Conference of Experts recommended supplying new instruments to the existing world network of seismic stations. The PSI believes that this recommendation should be implemented within the next year even if it must be done unilaterally by the U.S.

Lloyd V. Berkner (Chairman)
Victor H. Benioff
Hans A. Bethe
John Gerrard
David T. Griggs
Jack H. Hamilton
Julius P. Molnar
Jack E. Oliver
Frank Press
Carl F. Romney
Kenneth Street, Jr.
John W. Tukey

APPENDIX

I. Analysis of Long-Period Surface Waves

Long-period seismograph data (periods greater than 5 seconds) available from HARDTACK II and natural earthquakes suggest additional criteria for the identification of seismic events as natural earthquakes. In the yield range 5KT-23 KT, stations at distances up to at least 3500 km can provide the necessary data, in the absence of microseismic storms. The capability of the Geneva System for the identification as earthquakes of seismic events equivalent to 5 kilotons or larger by the analysis of long-period surface waves is conservatively estimated at 25% and may be much larger. Estimates of capabilities are based on observations with instruments not designed for this purpose. The use of specifically designed equipment should further improve the estimates of capabilities.

On the basis of present technology, it is concluded that the following techniques are available:

a) Love-Rayleigh wave amplitude ratio. A preliminary study of amplitude ratio of Love waves to Rayleigh waves for periods greater than about 10 sec. from earthquakes and underground explosions has been conducted at the Lamont Geological Observatory at Palisades, New York. The results indicate that in the equivalent magnitude range 5 KT-23 KT a single station at a distance of 3500 km or less can identify about 10% of seismic events as natural earthquakes. Data from stations in appreciable different azimuths are relatively independent and so increase the probability of identification significantly but not above some as yet undetermined limit.

b) Spectra of surface waves recorded on long period, horizontal component seismographs. Data from Palisades, Pasadena, and Berkley indicate a systematic difference in the long period spectra of earthquakes and underground nuclear explosions. Although the effect is striking, it is not possible to quote the capability of this method at this time except to estimate that identification of earthquakes from a network of stations is no worse than 10% and the upper limit is open.

The possibility exists that further results can be obtained in the immediate future by additional studies of the amplitude ratio for Love-Rayleigh waves and its aximuthal dependence for earthquakes. This will provide additional data to verify the estimate of 10% identification of earthquakes and examine the possibility of increasing this figure.

II. Network of Unmanned Auxiliary Seismic Stations

Interpolation of unmanned automatic seismic stations into the grid of control posts of the Geneva plan gives promise of providing

significantly greater information on weak seismic events, corresponding in intensity to one kiloton. A triangular network of such unmanned stations is suggested, spaced 170 km apart between the stations of the 1000 km grid proposed in Geneva for the seismic regions of the world. In such a network, a one kiloton shot coupled seismically to the same degree as Rainier, Logan, and Blanca would give 50 millimicron amplitudes or higher for first motion of P-waves at nine stations on the average. Thus data from single vertical-component seismometers disposed in such a network would suffice to detect first motion with reasonable certainty.

The practical problems of installing such a network may be estimated by noting that the spacings mentioned above imply having 35 auxiliary stations per main station and that the maximum communication distance between a main and auxiliary station is 600 km. Each auxiliary station would require a seismometer, a recording device (for providing a permanent record), a clock, a radio transmitter, a source of electric power, and probably a data storage device which will permit compressed data transmission as required. The cost of the technical apparatus needed for a single station, when manufactured in large quantities, might be ten to thirty thousand dollars. Access roads (or helicopter pads), installation and related costs may run the total costs up considerably higher, depending on local conditions. Periodic maintenance and record retrieval would probably be required at 30 to 60 day intervals.

The need for this network of auxiliary stations is clearly greatest in the areas of the world where earthquakes occur with high frequency. It might be acceptable to limit application of the network only to these areas, possibly 20% of the land surface of the world. Also one could tailor power and communication arrangements (possibly using wire lines in some places) according to the local facilities available.

If this network could be installed and effectively operated, it would very greatly increase the capability of the Geneva System for identifying those seismic events which are earthquakes, occurring in interior areas and corresponding in intensity to underground one kiloton or larger shots. The practical difficulties of installation, maintenance, and operation of the system, especially in remote areas, should not, however, be underestimated, and the possibilities for occasional spoofing must be recognized.

III. Larger Arrays of Seismometers at Manned Control Posts.

On the basis of present knowledge, replacing 10 distributed seismometers in a 3 km x 3 km square as recommended for each control post in the Geneva System by 100 distributed seismometers in the same square would affect the signal to noise ratio at frequencies near 1 cycle

per second as follows, using specifiable techniques:

(1) It is reasonably certain that an improvement at most stations by a factor of between 1.5 to 2.5 will be obtained;

(2) There is reason to hope for improvements in the range from 2.0 to 2.5;

(3) Increases from 10 to 10k stations should provide improvement by a factor from $k^{0.2}$ to $k^{0.4}$ for $k = 10$.

(4) Data which can be obtained within one month will provide a much firmer estimate of what may be expected. The data to be obtained include, most importantly, data on coherence of noise at station separations of 150 to 1500 feet, and secondarily, data on dependence of typical noise levels on wind velocity.

(5) When more is known about noise characteristics, it may well be possible to gain further improvement by applying other analytical techniques to a 100 seismometer array.

January 7, 1959

MEMORANDUM for Dr. J. R. Killian, Jr.

Subject: Value of Nuclear Test Control System to Research in Geophysics

In connection with its current review of measures which would improve the seismic capabilities of the detection system recommended by the Geneva Conference of Experts, the Panel on Seismic Improvement, appointed by the Chairman of the President's Science Advisory Committee, wishes to call specific attention to the value of such a detection network to research in geophysics. This statement is submitted separately from the initial report of the P.S.I., dated 7 January, since the subject lies outside the immediate charter of the P.S.I.

The network proposed by the Geneva Conference of Experts for monitoring nuclear explosions has great potentiality for research in geophysics. The IGY program demonstrates how major advances can be made by world-wide observations with a network of uniform stations having instruments of advanced design.

The scientific results which can be anticipated in many fields of geophysics from full exploitation of the Geneva network would merit the establishment of such a net for scientific purposes alone. We are best equipped to assess the contributions to geophysics of the solid earth.

Our present picture of the interior of the earth has been pieced together largely from scraps of information gleaned from seismic waves which have traversed the depths to varying degrees. Current theories of the genesis and constitution of the earth, of the origin of continents and mountains now cry for an order of magnitude increase in the precision of seismic data to provide confirmation or disproof.

The establishment of the high quality seismic stations proposed by the Geneva Conference of Experts--if exploited for geophysical research (which would not in any way interfere with normal operation of the net)--would hold the promise of advancing our seismological

capability to a very large degree. If this net were augmented in the various ways proposed by the present conference, and if the research and development programs discussed here were actively pursued, the advance would be spectacular. If this net, suitably augmented by portable stations, were tested by large H. E. and occasional nuclear shots under international auspices, then the utmost dream of U. S. seismologists would have come true.

The above has assumed that the seismic detection net was exploited for geophysical research purposes. It is our firm belief that unless this possibility is firmly built into the treaty, competent seismologists will not be attracted into the international organ which administers the net. If competent people are not so attracted the potentialities of the net for routine seismic detection of earthquakes and explosions will never be realized.

Lloyd V. Berkner (Chairman)
Victor H. Benioff
Hans A. Bethe
John Gerrard
David T. Griggs
Jack H. Hamilton
Julius P. Molnar
Jack E. Oliver
Frank Press
Carl F. Romney
Kenneth Street, Jr.
John W. Tukey

Next 3 Page(s) In Document Denied