U.S. delegation (center) at the Geneva Conference (1959). First row: Professor Wolfgang Panofsky (Stanford), Dr. James Fisk (Bell Labs), Dr. Carl Romney (USAF). Second row: Dr. Harold Brown (Livermore Laboratory), Prof. Frank Press (Caltech), Prof. A. Turkevitch (U. of Chicago), Prof. Hans Bethe (Cornell), Prof. J. Tukey (Princeton). USSR delegation is at right, U.K. delegation (not seated) at left.

Scientific Aspects of

The Nuclear Test Ban

by Frank Press

The negotiations for a nuclear test cessation have been going on between the East and the West since 1958. These negotiations have been unique in many respects, particularly in that scientists initiated the talks in an attempt to lay a scientific foundation on which the diplomats could then build.

Now, there are many pitfalls in putting scientists from East and West together in a room and telling them to behave like scientists, knowing full well that the ultimate decisions must be based on non-scientific questions. But this is a long story in itself and I won't go into it. However, the use of scientists was a new concept in international negotiations, and many of us were unfamiliar with the role that we had to play, of being scientists and yet being cognizant at the same time of the political implications of any positions that were taken.

The nuclear test cessation treaty is now partially written, and a number of articles have been agreed upon by the East and West. Such issues as the concept of "on-site" inspections (field investigation of suspicious events), the immunities and privileges of the monitors, and the makeup of the inspection and monitoring teams have been settled.

The remaining articles are some of the most difficult ones, and they are still being negotiated. One of the most important of these deals with the number of inspections that will be permitted each year. Of course, this is one of the crucial aspects of any monitoring agreement, and if the Russians insist on no more than two or three inspections a year, I don't see how we can make any progress toward a successful treaty.

At the present time, the proposed monitoring system would be able to deal with underground nuclear

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explosions of somewhere between 5 and 20 kilotons. The bombs that were used during the war were about 20 kilotons. Smaller explosions are not now identifiable as suspicious events. Explosions in the atmosphere offer no major problems. Explosions in outer space are feasible, and of uncertain use. It is questionable whether they can be detected, and it is difficult to gage their significance as a factor in a test cessation treaty.

The decoupling method

A major problem has recently been posed for this treaty – namely, the possibilities of exploding nuclear devices in large cavities. This is known as the decoupling method, or the "muffling method." It is interesting to me that the greatest improvement in detection and the greatest degradation in detection were made by investigators of the same organization – the RAND Corporation. They have recently shown us how to improve our monitoring capability from 20 kilotons down to about 5; and yet they have also discovered how to hide these explosions in large cavities.

The possibility of decoupled explosions is something we have to live with. The decoupling theory has recently received experimental verification in tests involving small chemical explosions. Now, one doesn't go around blithely shooting explosions in large cavities. For one thing, it is expensive. It might cost anywhere from $5 million to $20 million to dig one of these holes. Furthermore, it will take something like two years to excavate a hole large enough for a 5-kiloton explosion. Such an excavation is a major effort, involving a lot of men and equipment. It is the sort of thing that could be difficult to hide from intelligence agents.

The present technology limits us to holes in salt (where they can be dug by using hot-water solutions), but I think it is quite possible that ways will be found at not too much greater expense to dig these holes in other rocks; and if a nation is willing to spend enough money, it might even be able to make a hole in granite. This has not been fully studied. There is a whole new technology of excavating underground cavities which now must be explored in order to anticipate the possibility of clandestine testing. Unfortunately, we must realize that if a nation wanted to conduct clandestine tests by means of shooting in large cavities, it probably could succeed so far as the present technology is concerned. It is not an easy job, but it is one that is quite feasible.

Now, recognizing the difficulties of detecting small explosions, Prime Minister McMillan and President Eisenhower made a very sensible proposal. They suggested that we enter into a treaty with the Russians for explosions of 20 kilotons and larger, with an appropriate number of monitoring posts, inspections, and so on, and that we enter into a moratorium with the Russians for the smaller shots. The moratorium might last about two years – the exact length is another political question. During the moratorium, both sides would conduct a joint research program in an attempt to find ways to improve detection so that the smaller explosions which are now not detectable can be brought into the treaty. This is a very reasonable approach, and it seems to me to be the only way out of a very difficult situation. Admittedly there is a risk in going into this treaty – but there are also some returns.

The treaty represents a first step in opening the countries of the world to inspection – a small step indeed, but one which is preliminary to progress in disarmament. It would give us experience in implementing controls under a treaty organization to see if further disarmament proposals are feasible. Of great importance is the hope that the treaty would inhibit the development of nuclear weapons by other countries.

A controlled monitoring system

After the moratorium research program is completed we will be in a better position to specify the monitoring system needed to provide adequate control. If political restrictions on the number of stations and the number of inspections, and the use of unmanned stations, are not excessive, a feasible monitoring system might deter clandestine tests. Then again, it might not – and it would be risky for us to enter into a treaty. It is dangerous to anticipate the results of research and to predict the outcome of the political-scientific deliberation that determines what detection capability represents an acceptable risk.

There is not, by any means, unanimous support in this country of the proposed moratorium. Many Americans who have made tremendous contributions to our national security see pitfalls in such a moratorium. It will diminish our security by inhibiting development of those weapons needed to improve our defense.

Where do we stand now? During May of this year, we met with the Russian scientists to discuss the moratorium research proposal and many of us were surprised. The Russian scientists supported the moratorium research program and agreed in principle to participate. They even said that they would allow us to use nuclear explosions during the research program even though they would not conduct any nuclear explosions themselves. They placed certain restrictions, however, on the use of nuclear explosions – some of which were reasonable. They insisted on the privilege of examining each nuclear device in detail – opening it before it was detonated – in order to

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make sure that we were not developing weapons under the subterfuge of a research program to improve detection. I think this is a legitimate request on their part, and I think that this is something which eventually could be agreed upon, subject to Congressional approval.

The Russians also insisted on the privilege of participating in the planning of the experiments. They wanted to be real partners in this study – and we would have been delighted to have had them as partners.

A more difficult problem arose when they said that they would not countenance any decoupling tests during the research program. They frankly admitted that their position was not a scientific one but a moral one. It was immoral, they argued, to try to find better ways to hide nuclear explosions. We attempted to point out to them that there would always be a cloud of uncertainty over the treaty until we could resolve the decoupling problem – or, at least, until we completely understood its implications. Without some decoupling tests we could make no progress in attaining these goals.

It is difficult to predict how this will go – whether the Russians will be adamant on this question, or whether it is negotiable. I, for one, do not see how we can agree to a moratorium research program without some decoupling tests.

A nuclear test cessation treaty

I believe that if there is going to be any progress toward disarmament, the first step is a nuclear test cessation treaty along the lines of the McMillan-Eisenhower proposal. A major impediment is the number of inspections. The Soviets are very leery of inspectors on their territory, as we all know. They have placed, essentially, a political strait jacket on all progress in the sense that they are limiting us, for political reasons, to an inadequate number of inspections.

It is quite impossible to feel secure with a treaty that allows too few inspections. This follows because of the large number of natural events – perhaps in the hundreds each year – which are inseparable from explosions. For all of these suspicious events, the Soviets propose to allow us only several field inspections each year. Clearly, the chances for violation are very large under this circumstance. The fact that we are asking for a few tens of inspections is in itself a concession, because we are not asking to inspect every single suspicious event (which is what we would like to do) but only a very small percentage.

This is not something that is readily negotiable. It is not the case that the geometric mean between both points of view – or the arithmetic mean – will leave us with proper safeguards. After the research program, we will be in a better position to set the number of monitoring stations and annual inspections that are *really* necessary.

Another indication of the strait jacket that the Russians are putting on us by their obstinate desire to keep their country closed is the following.

There is only one suggestion now on the books that might provide some security against decoupled shots. This is the suggestion made by Professor Hans Bethe. He proposed that we increase the number of monitoring posts by setting up unmanned stations – instruments which telemeter their information without requiring local personnel. With a network having an instrument spacing of a few hundred kilometers, decoupled shots would be detected and might be identified as suspicious events. This is a sound proposal but, in the present framework of the negotiations, it is not admissible because of the Soviet position.

I think another impediment is the fact that there is no solid American position on this question. The President is in the difficult situation of receiving conflicting recommendations from his advisors. This does not make for a very strong American position at Geneva.

Resuming nuclear testing

There is increasing pressure in the U.S. to resume testing, not only for the development of weapons but also to get on with our own research program to improve detection. Very soon we are going to have to face up to this question. The Russians now have a moratorium which is not policed. Like an Irish wake, they would like this to go on forever, because they have everything they want and they give nothing in return. They have slowed development on weapons needed for our security. We cannot be certain that they have given up testing, although there is no direct evidence that they have detonated nuclear explosions during the negotiations.

Sooner or later, we are going to have to take stock and put a time limit on the negotiations for the treaty. We must make a reasonable attempt at negotiations, however, for abrupt test resumption could be embarrassing to us and might bring censure from many of the nations of the world. I hope that if we resume testing independently it is only after a yeoman's effort in Geneva to reach a treaty with reasonably adequate safeguards. It may require a summit conference devoted to this one problem. Difficult though such a treaty may be to realize, I think this is the easiest of the disarmament questions before us.

We are now actually engaged in our research program to improve detection. The U.S. Government is presently spending some tens of millions of dollars each year to improve detection techniques. This is all unclassified research, and much of it is being con-

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ducted in the universities. Nuclear explosions have not yet occurred. We hope to conduct these jointly with the Russians as part of a moratorium research program, if such cooperation is possible. Otherwise we may have to go it alone. I think that this program is something we really can be proud of; it shows the world that we are working to make a treaty possible.

Let me give you some examples of the projects that are now under way. A typical monitoring post of the kind that will be spread throughout the world has been completed and placed in operation. We can evaluate its capability. It is a post which is quite large; it includes an area of many square miles, with tens of seismographs within the area, and a large technical staff. A number of similar stations will be built soon. These are the treaty-type stations which were accepted by both sides in 1958.

In addition, the government has just funded an improved station which incorporates the advances that have been made since 1958. This improved station will have many more detectors, improved instruments, computing machines, and, possibly, digital seismographs. It will include all of the sophisticated analytical and instrumental advances that have recently been made.

Caltech's program, for example, is to make a digital seismograph for processing directly by a computer. We are also interested in making extremely sensitive seismographs by finding optimal spectral bands to record in. We are studying the long waves of earthquakes and explosions in the hope that these long waves may be a new diagnostic feature which distinguishes earthquakes from explosions. It may interest you to know that these wavelengths are of the order of 100 km-lengths which are long compared to most discontinuities on the earth's surface.

The Bell Telephone Laboratories have taken up the problem of depth of focus. If we can precisely determine the depth of focus of an earthquake, most earthquakes will be eliminated as suspicious events since they typically occur at depths greater than those at which explosions are likely to occur.

Stanford University, together with the University of California, is studying the aftershocks of earthquakes. One feature of an earthquake is that very often there is another one at the same place within a few days. A nuclear explosion is not likely to be followed by an aftershock. These groups are gathering more precise statistics on aftershocks of earthquakes.

Some firms drawn from the oil industry are engaged

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in such problems as how to locate a decoupling hole at a depth of a thousand feet. What measurements can be made at the surface to locate one of these holes? These are difficult problems as is the following one: If a certain number of inspections are allowed per year, what will the inspectors look for? Any violator will make sure that the surface is smoothed over again, that any evidence is removed. These inspectors must now find a way to locate fission products at a depth of a thousand feet in a hole that may be a hundred feet in diameter. This is not an easy job.

The Scripps Institute of Oceanography at La Jolla, and Columbia University in New York are making deep-sea seismographs. This may seem like a strange thing, but scientists at Columbia have shown that the bottom of the ocean is one of the quietest places to put an instrument; the noise is very low, and with a low noise-level, a more sensitive seismograph can be built to detect smaller explosions.

One of the most interesting aspects of the research program to me is what we call the "giveaway" program. The U.S. Government is essentially going to re-equip the seismograph stations of the world. This is perhaps the greatest single act of progress that geophysics has seen. It is like giving away one hundred 100-inch telescopes to observatories all over the world, or giving 100 cyclotrons to 100 universities all over the world. I hope you do not think me bizarre if I say that if all else fails, and the negotiations blow up, at least we will have greatly improved world research in geophysics. Now the government doesn't give money away without reason, and their support of the "giveaway" programs is in the interest of improving seismic research all over the world. It may turn out that a researcher in some remote country, stimulated by this new equipment, will come up with a significant improvement.

I think this shows the firm intention of the U.S. to go ahead and try to improve the technology so that a treaty is possible. Two years from now, we will have completed much of our research program, and we will have learned a great deal. I don't know how much better off we will be insofar as detection of explosions is concerned. I think that, no matter what happens at the end of two years, the final problem, again, will be in the hands of the diplomats. However we will be better able to advise our diplomats about the state of affairs, so that the final diplomatic decision will rest on a more secure scientific foundation than is now possible.