APPENDIX C

CONCEALMENT AND DETECTION OF NUCLEAR TESTS UNDERGROUND

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I. General

Complete containment of a test explosion underground, though devised as a method for making testing easier by eliminating fallout,

[redacted]

Such an explosion provides no electromagnetic signal, and the

[redacted]

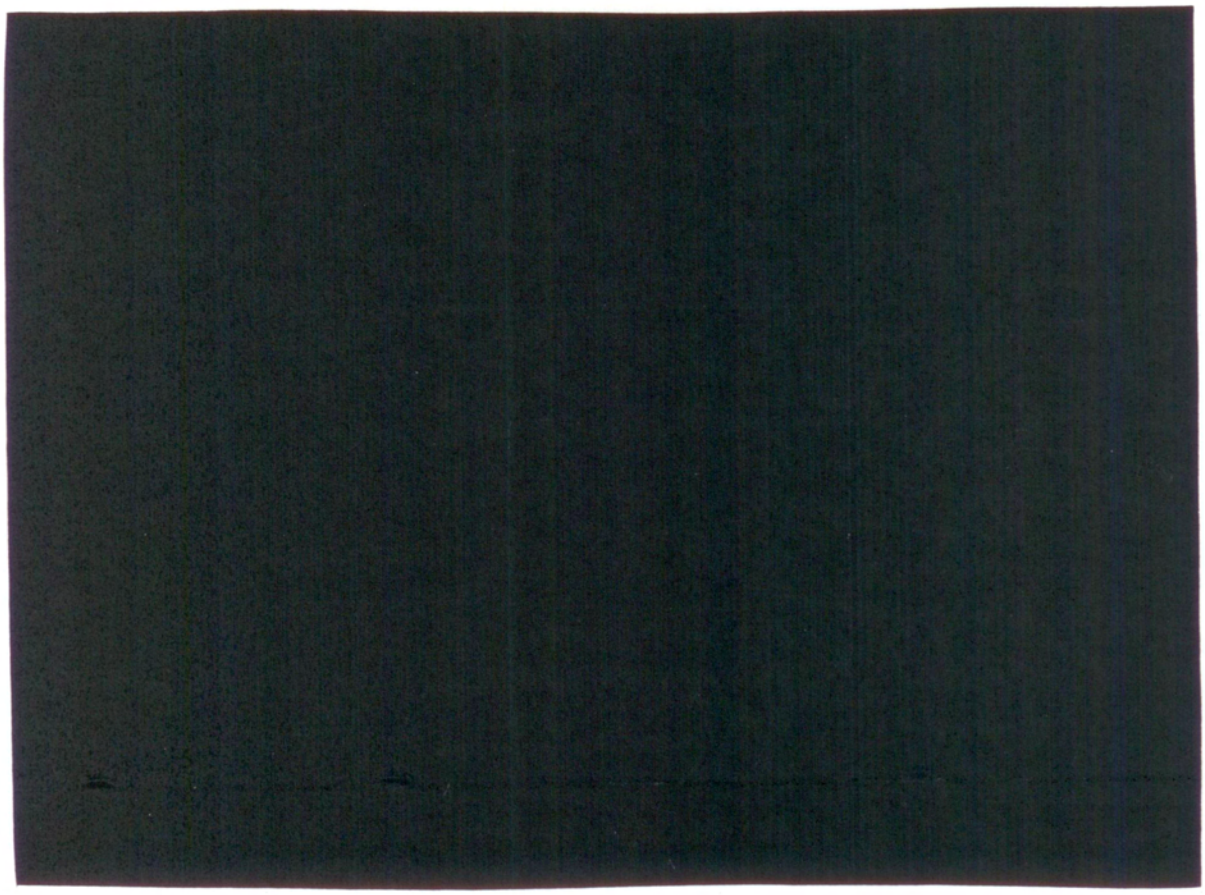
No activity is released into the atmosphere, so that the only detection method is the seismic. To provide proof by scientific means the residual activity from the explosion must be located underground and sampled.

II. Results from Rainier Test

The only such shot carried out in this country which casts any light on such procedures is the Rainier shot of Operation Plumbbob.

[redacted]

[redacted]



Preliminary estimates indicate that a test operation can be carried out more cheaply underground than on towers and balloons. The diagnostic stations could also be underground for clandestine tests (in fact they probably will be even if the tests are not hidden). Keeping underground tests secret will increase the costs by preventing the use of a single diagnostic bunker for many shots on the basis that more than one in a given vicinity increases suspicion and the possibility of proving a violation. It may mean that each shot must be in a completely different area, but this conclusion may be modified to some extent, because also natural earthquakes have aftershocks. In any event, such extra costs are associated with clandestine tests generally rather than underground tests specifically and are not likely to be more than a few million per shot, which is not a large percentage increase.

IV. Dependence of Seismic Signal on Yield and Medium

On the basis of observations, it is believed that the amplitude of the earth motion from an underground explosion increases as the

1.2-power of the energy released. This scaling law is obtained on the basis of explosions of conventional explosives underground (quarry blasts). The law is somewhat surprising; theoretically one would expect that the seismic amplitude would go as the square root of the energy release. The empirical law has been used in Appendix A to predict the frequency of earthquakes in the USSR which might be confused with subsurface shots of various yields. The empirical law clearly gives more larger results for the seismic signal to be expected from shots of larger yield than Rainier than the "theoretical expectation" would give.

The empirical law indicates that a larger fraction of the energy release goes into seismic waves at higher yield. This effect certainly must stop at some point; at about 100 kilotons the entire energy would be converted into seismic energy if the 1.2-power law held up to that yield. Experiments are urgently needed to establish the actual relation between yield and seismic signal. These should be carried out with nuclear explosions since conventional explosives may not give the same effect due to the evolution of large amounts of gas.

The seismic signal will depend strongly on the medium in which the test is conducted. The volcanic tuff in which the Rainier test was conducted probably gives a relatively small seismic signal; it is only equivalent to an air shot of about 20 times greater yield. Hard rock would almost certainly give a stronger seismic signal while on the other hand it may contain the radioactive products in an even smaller volume. On the other hand, unconsolidated material which is found in many places near the surface of the earth may well reduce the seismic effects below those observed in the tuff because the signal should decrease with decreasing yield stress, and unconsolidated material may have a yield stress as low as one-tenth of that of tuff (which has about 10,000 psi).

[redacted]

[redacted]

It is likely that reduction of seismic signal is easier for low-yield shots than for high-yield ones. Unconsolidated material is found only in the top layers of the earth and the required burial depth increases with yield, so that it may be difficult to find such material

[redacted]

V. Identification

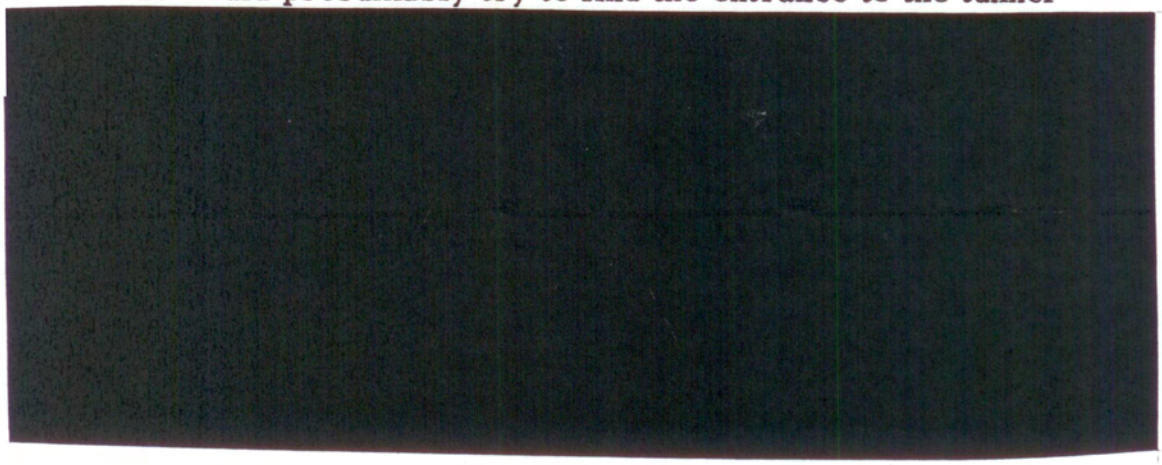
It is shown in Appendix A that the seismic wave from a 1-kiloton subsurface explosion in surroundings similar to those of the Rainier shot will be detected by the net of seismic stations proposed for the USSR in that appendix. However, there are about 2500 earthquakes per year in the USSR which give signals of similar strength. The most promising feature of seismic signals from underground explosions distinguishing them from earthquakes is that the first pulse from explosions always corresponds to compression while the first pulse from an earthquake is compressive in two quadrants, while it corresponds to dilatation in the other two. It is estimated in Appendix A that there will be about 300 earthquakes of strength equivalent to 1 kiloton or over which will give signals in the proposed seismic detection net which cannot be distinguished from nuclear explosions and therefore will require further investigation on the spot. If the limit is set at 5 kilotons the number of unidentifiable earthquakes will be about 35.

It should be pointed out that 1 and 5 kilotons refer to the size of the seismic signal, not to the actual yield. By proper choice of the

medium as discussed in Section IV, tests of 10 kilotons might be made to look like a normal 1-kiloton explosion, and perhaps, with more difficulty, 50 kilotons to look like 5. According to seismologists, it is unlikely that a nuclear explosion could be so conducted (by proper shaping of the explosion chamber) that the signal is dilatational in some directions.

The seismic signals would locate the source within about 5 miles. Investigation on the spot will then be necessary to decide whether the signal could be due to a test, this is described in Section 3e of Appendix A.

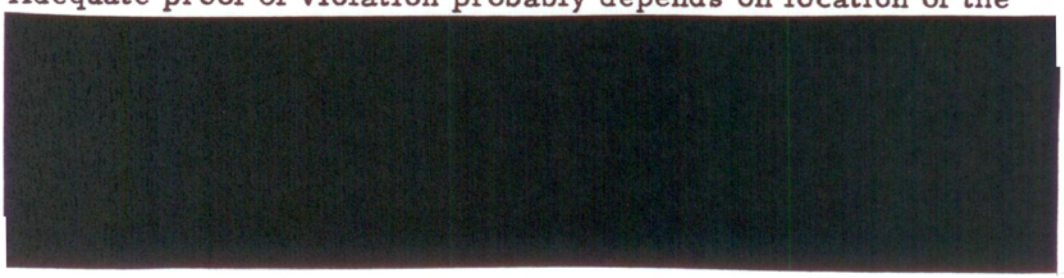
One would presumably try to find the entrance to the tunnel



To summarize:

1. Detection of underground shots depends entirely on a seismic net. Identification depends on local investigation.

2. Adequate proof of violation probably depends on location of the



3. Adequate diagnostic information for weapon development can almost certainly be obtained at no great increase (and perhaps some decrease) in cost by testing underground. [redacted]

4. Experimental data is lacking or insufficient and should be acquired either prior to or as part of an agreement on the following subjects:

[redacted]

(c) Possible distinctive characteristics of underground explosions which will enable them to be told surely from natural earthquakes. This includes the seismograph records at a distance, and earth motions nearby. Possible special chamber design to remove such distinctions if any are found to exist must also be studied.

(d) Use of acoustic sounding from above the surface to detect the disturbed region below the surface. This has not yet proven feasible even from inside the tunnel.