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The Commanding General
Air Research and Development Command
Post Office Box 1395
Baltimore 3, Maryland

LOS ALAMOS

THIS DOCUMENT CONSISTS OF 3 PAGE(S)

Attention: RDDN



Dear Colonel Isbell: 02016314

Thank you for your letter of 12 January. Please excuse the delay in answering it; I am in the middle of moving our research project to the Hawaiian Islands and have not, until now, had an opportunity of giving undivided attention to the very important topic raised by your letter. The priority of the topic, indicated in the second paragraph of your letter, justifies both the informal style of my answer and its length. I feel that I should explore as thoroughly as possible those points which, in the interests of brevity, had to be omitted from my report.

First, I must give the positive evidence which led me to assume that the mushroom cloud lay in the troposphere. Within a few minutes of the detonation (I forgot how many now, and I have kept no notes) we made a vertical angle measurement on the edge of the mushroom of 92°, in other words, we were at that time just under the edge of the canopy. The details of the cloud overhead were very plain. It consisted of liquid water, at least in all parts which were visible; the edges were hard and bright and, in places where fragments were detached, it had the structure of altocumulus mixed with altostratus. Since it remained in this condition for a considerable time, long after any intrinsic upward motion due to differences in temperature between it and its environment had ceased, it could not have had its base at 60,000 feet but rather somewhere in the layer 25,000-45,000 feet. At 60,000 feet, the temperature in the cloud would be very much below -40° C and the whole cloud would consist of ice particles. The appearance would be quite different from that observed. I watched the mushroom cloud for almost two hours after the explosion; the various parts of the deformed cloud were readily distinguished from natural clouds, which formed in the vicinity, by their colour, characteristically pink or, rather peach-coloured. Although some parts of the tops of fragments had been transformed to cirrus, most of the derivatives of the cloud assumed typical tropical altostratus form. Moreover, rain continued to fall from parts of the cloud, and, in profile and except for the colour of the parent cloud, the rain looked similar to altostratus precipitation typical of the Marshall Islands in disturbed weather. In addition to this, both Major Stopinski and myself had observed certain fragments of natural cirrus (certainly lying within the troposphere) which were almost overhead just before the explosion. The advancing edge of the mushroom cloud stopped in such a position as to underlap part of this natural cloud. Several competent observers agree with me in saying that the edge of the mushroom was lower than the natural cirrus, which was, indeed, relatively undisturbed by its advance. So much for the gross observable structure of the cloud.

Now we come to another kind of evidence. The winds for the day are very well known up to and above the tropopause. If the bulk of the cloud had been in the stratos-

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW	
1ST REVIEW DATE: <i>07-02-97</i>	DETERMINATION (CIRCLE NUMBER(S))
AUTHORITY: <input type="checkbox"/> AOC <input type="checkbox"/> ADC <input type="checkbox"/> ADD	1. CLASSIFICATION RETAINED
NAME: <i>R. Brown</i>	2. CLASSIFICATION CHANGED TO:
2ND REVIEW DATE: <i>10-22-97</i>	3. CONTAINS NO DOE CLASSIFIED INFO
AUTHORITY: ADD	4. COORDINATE WITH:
NAME: <i>R.A. Carpenter</i>	5. CLASSIFICATION CANCELLED
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phere as it has to be by the alternative theory, the movement of its several parts some hours later would have been quite different from what they were. As far as my information goes, there is little doubt that these derivatives moved with the winds in the level between about 35,000 feet and 60,000 feet. On the other hand, as the sunset observations show, the plume did penetrate the stratosphere, and moved with, and was deformed by, the winds appropriate to that region; it may well have reached 134,000 feet.

Now let us consider the alternative hypothesis based on unspecified measurements: that the base of the mushroom cloud was at 50,000 feet and the top, apart from the plume, was at 120,000. Of course, I do not know the nature of the measurements, but some of them, at least, were probably of the type usually made on such occasions, the interpretation of which has in the past led to considerable error in the estimate of bomb cloud heights. Angular measurements alone, whether with theodolite or sextant on the ground or by bubble sextant from aircraft, are subject to the same erroneous interpretation. If the cloud, on reaching some limiting height, advances not vertically but laterally toward the observer, there will be a very rapid increase in vertical angle, which if interpreted as vertical movement, will lead to gross over estimates in the height of the top. This error was made with GEORGE shot during Operation GREENHOUSE. On the basis of the misinterpretation the height of that cloud was announced as over 85,000 feet, whereas the true height as measured from photographs long afterwards was considerably less than this. Owing to the enormous lateral extent of the MIKE cloud the chances of this kind of misinterpretation have been greatly enhanced. For example, if I had made this interpretation of our own angle measurements, crude as they were, I would have had to conclude that within a very few minutes after the detonation, the mushroom cloud had reached to an infinite distance from the surface of the earth.

Even radar measurements are not free from this objection, since it is difficult to be sure what part of the cloud is being measured: is it the active plume or is it the edge of the mushroom cloud? Is it perhaps a knot of reflecting material buried somewhere in the cloud? I cannot answer these questions, since the original data are not available to me, but I suggest, in view of the importance of the topic, that they be asked. The only reliable way of directly measuring the cloud height is to triangulate all parts of the explosion product by means of a network of special cameras. The difficulty with MIKE was that no one seems to have anticipated the great size of the final cloud or the fact that it would set up so much secondary natural cloud and precipitation that complete triangulation would be difficult - it is hard to recognize the same parts of the cloud different photographs. This apart from the fact that very special wide-angle lenses ought to be used on all cameras, and that this, apparently, was not done.

I venture now to suggest certain theoretical reasons why the mushroom cloud lay in the troposphere and not in the stratosphere, chiefly because I think these may help in solving your operational problem. It seems to have been generally assumed that the MIKE cloud differed in no essential way from that formed by conventional shots, except, of course that it was much larger. My own hypothesis on this is, that MIKE was so large that qualitatively different geophysical effects were produced and that it is erroneous to extrapolate from the Nevada shots, say, or even from previous tests in the Marshall Islands. A conventional air-drop, for example, results in the formation of a fireball, which, after being transformed into a ring-vortex, ascends to the tropopause. The vortex ring or mushroom head consists of original bomb material plus water, etc., entrained into it by turbulent mixing; the stem is largely secondary although it too contains radio

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active material left behind in the "wake" of the ascending vortex-ring. Compared with the scale distance (ground to tropopause, about 55,000 feet) the fireball is not large and the bomb material and heated gases have a chance to form a structure, the mushroom top, that has a relatively long life. It is quite otherwise with MIKE shot. The fireball diameter is now an appreciable fraction of the scale distance, its top, at formation extends into the middle troposphere and its energy content is huge. It is quickly transformed into a fiery column (I called this the primary stem) which immediately penetrates the tropopause and does not come into equilibrium with its environment until it has reached 134,000 feet or, as I suspect, greater heights. Probably no ring vortex is formed, but only a "plume" which later hangs and is deformed in the stratosphere. In that region it probably becomes very stable in stratification and has a long life-history.

The greater energy of this fiery cataract sets up a secondary circulation in the surrounding atmosphere below the tropopause. Huge volumes of outside air are entrained in this circulation, comparable now in size, though not in intensity, to an incipient typhoon. The sudden formation of the thick secondary stem and its streamlined features indicate that it and the mushroom top consist of condensed water from air outside the primary stem, constituting a circulation induced by the latter. In the mushroom there are other materials beside air and water vapor of course. Coral fragments and condensed steam from the ocean are probably swept up initially and later heavy bomb particles may fall from above or be incorporated in other ways. A very elementary calculation, however, shows that the mushroom consists of material that could not possibly have all come from these sources or from the original bomb material. It is precisely because the mushroom cloud is not primary, but is the visible part of a secondary circulation, that it is confined to the troposphere; this explains also why, it appears to advance so rapidly in a lateral direction.

The operational implications of this hypothesis are interesting. The dangerous part of the total cloud will be in the stratosphere, but here the column should be reasonably narrow. An aircraft flying above the tropopause ought to be able to avoid too close proximity to the plume, provided appropriate parachutes are developed for the drop. There remains the hazard from the mushroom, which under certain conditions could be reached chiefly through secondary contamination. If the above hypothesis is sound, the best operational level for the drop aircraft would probably be 65,000 or 70,000 feet. This being difficult to achieve at present, it would probably not be serious if the aircraft was overtaken by the lower edge of the mushroom at, say, 30 miles and 40,000 feet, for if the hypothesis holds, the major concentration of contaminants outside the primary stem and plume, would be in the mushroom just below the tropopause. I presume you have information on this.

As you can see, the evidence upon which the report was based is simply that which any observer of MIKE shot could collect. In the light of your more detailed knowledge you should not put too much weight on it. I have seen no photographs and am relying entirely on memory of the events, a notoriously unreliable proceeding. However, the theoretical reasons for believing that MIKE was altogether a different and new geophysical phenomenon are well founded.

Sincerely yours,

/s/ CLARENCE E. PALMER
Professor of Geophysics

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