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STATUS OF INVESTIGATION OF THE NORTHERN ARIZONA STRATOSHPERIC CLOUD OFFEBRUARY 28, 1963

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I. General. This report on the continuing study of the unusual ring-cloud that was observed over the Flagstaff area near sunset on February 28 has been prepared for the information of the many persons who have assisted in this investigation. I had hoped that a fairly complete summary of the work might have become possible some weeks back, but new questions have arisen that are not settled even yet. Nevertheless, a summary of recent findings will be made here.

Approximately 175 letters have now been received from persons who observed the stratospheric cloud. Correspondence with those who indicated that they had taken photos has led to a present total of 85 photographs from 35 different localities in Arizona and New Mexico. In addition, two short movies have been received, though little cloud motion is apparent on either of them.

A preliminary scientific report on the cloud has recently appeared in Science, Vol. 140, No. 3564 (19 April 1963), under the title, “Stratospheric Cloud over Northern Arizona.” The cover photo of that issue is a shot of the cloud taken by C. E. Peterson of Bremerton, Washington. A photo taken in Springerville, Ariz., by I. E. Daniels accompanies the text.

A set of four photos of the cloud will be found in the May 17, 1963 issue of Life, along with a brief discussion and plea for further photos.

The Science article, and still more the Life article, have led to a new surge of correspondence on the cloud and on certain observations of other seemingly similar clouds to be discussed below. In the latter category are about 75 letters, with more coming in daily at the time of this writing. So far, only a few good photos have been turned up as a direct result of the Life appeal; but one of those (taken by F. H. Carver of Page, Ariz.) is of such quality as to repay all of the effort that went into getting the plea for more photos into Life.

II. Photo-site survey. I made a trip through central and northern Arizona in the period April 2-7 to make detailed triangulation observations of foreground reference features and distant check-points that appeared in each of about fifteen photos. This trip proved quite successful, and I take this opportunity to thank once more the many persons who cooperated in those surveys.

On April 20, I went to Lordsburg, N. M., to survey the site of a series of six photos taken by H. J. McSpadden. These six were of special value to the study because they were taken over a period of approximately one-half hour, at recorded times. (The unknown time factor in most of the photos remains a serious difficulty in photogrammetric analysis of the entire set of 85 photos.)

III. Present estimate of height, and related details.

A. Height. The survey work and the interviews in and around Flagstaff have revealed that the southern tip of the cloud lay about ten miles north of Flagstaff at about 1840 MST. This implies that the range of the cloud from Tucson was greater than the initially assumed 190 miles. Using the revised range plus the angles of elevation previously computed from the four photos taken in Tucson gives an altitude of 43 km, which equals about 140,000 ft. or almost 27 miles.

This revised altitude takes the cloud still further above the height-interval of even Arctic nacreous clouds, and puts it disconcertingly near the base of an "exclusion region" of the mesosphere in which the temperatures are so high (due to ozone absorption of solar ultraviolet radiation) that the saturation vapor pressure of water (or ice) exceeds the total ambient air pressure. In that exclusion region (typically from about 42 km to about 65 km), no water drops or ice particles can exist. Water can be present there only in vapor form. The indicated altitude of the Flagstaff cloud is slightly above the mean base of this exclusion layer, adding further interest to the entire phenomenon.

B. Motion. Although precise photogrammetry has not been worked out to yield final motion estimates, preliminary analysis of the McSpadden photos from Lordsburg indicate an eastward cloud drift speed of 95 mph for the upper limit, and 77 mph for the lower limit, the uncertainty being due to the unfortunate fact that, on the very first shot of this series, the time was uncertain to two minutes. An estimate of angular velocity of the cloud over Flagstaff has been mad by Robert A. Schley (using subsequently-checked times of two long-distance phone calls to obtain very close time-checks on his observations, made between the calls). His angular velocity, along with the present height estimate, gives an apparent speed of 110 mph.

There have been only a few reports of early sightings of the cloud (or one like it); but these have not fitted into any consistent pattern. The motion remains a rather uncertain feature, all in all. As will be seen below, this is unfortunate, for the cloud's motion enters critically into a test of one hypothesis as to its origin. It is hoped that the ultimate photogrammetric analysis will shed further light on this point.

C. Some distant sightings. Queries have been sent out to about twenty-five small-town papers in Arizona and surrounding states, and an A. P. wire story has gone much farther, asking for observational details. No sightings seem to have been made in California or Nevada, but some distant observations were reported from localities to the east. Evidently many saw it in central New Mexico, reports coming from Santa Fe,

Albuquerque, Alamogordo, Truth and Consequences, and Las Cruces. It was reliably reported by a woman in Center, Colorado. But the most distant sighting reliably checked was made in Juarez, Mexico, by J. H. Buels, of El Paso, Texas. Mr. Buels' location was approximately 380 miles from the cloud!

IV. Some excluded hypotheses. The true nature of the cloud cannot yet be regarded as known; but a few hypotheses have been definitely ruled out.

A. Contrail? Although this cloud initially seemed to many, including myself, much like a high jet condensation trail, it lay far too high to fit that simple hypothesis. Under the upper-air temperature conditions prevailing on the 28th, as shown by the Winslow, Arizona, radiosonde records, jet contrails could not have formed above approximately 24 km (78,000 ft). Furthermore, no operational aircraft can maintain steady horizontal flight at that altitude. Since the entire ring had a circumference of the order of 150 miles, and was essentially in a horizonal plane, it is quite out of the question to attribute this cloud to any kind of jet effect.

B. X-15? One American aircraft can fly well above 140,000 ft. That is the X-15 research aircraft. An analysis of the thermodynamics of combustion of the fuel used in the liquid-rocket-motors of this aircraft (liquid oxygen and ammonia) showed that it would produce contrails to a higher altitude than could a turbojet engine, but only by a few kilometers. The upper limit to X-15 contrail formation under conditions prevailing on the 28th was about 27 km, far too low to fit the cloud.

Furthermore, subsequent correspondence with officials at Edwards AFB, the home field of the X-15's, and with North American Aviation Co., wholly excluded the X-15 hypothesis, since no X-15 had been in the air for weeks prior to and for a number of days following the Flagstaff cloud appearance on the 28th.

C. Nevada Test Site atomic explosion? The cloud lay only about 250 miles east of the Nevada AEC Test Site, and westerly winds might conceivably have carried in some aftermath of an atmospheric test of some sort. However, officials of the Test Site reported no test activity of any sort occurring on that base that might have had any connection with the cloud.

D. Naval Ordnance Test Station activity? Looking still further upwind for a possible artificial source, one might consider the Naval Ordnance Test Station at China lake, Calif. Inquiries, however, turned up no activity there on the afternoon of the 28th, striking out that possibility.

V. A possible explanation - a Vandenberg AFB rocket explosion.

A. Thor booster explosion. A search of West Coast newspapers for the 28th disclosed a brief note on a intentional destruction of a military-satellite launch booster sometime on the 28th. Further information was found in the March 11, 1963, issue of Missiles and Rockets, which contained the following item: "The Air Force deliberately

destroyed a secret satellite, believed to be of the Discoverer series, after launching it aboard the 'souped up' Thor Feb. 28 from Vandenberg AFB. All four motors were ignited at launch, but deviation from the programmed trajectory forced safety officials to destroy the booster before payload separation. The thrust-augmented Thor (TAT) is a liquid-fueled Thor with three Thiokol solid rockets spaced around the Thor case. This was the combination's first test."

It became essential to find the time of this detonation and to explore further details bearing on the cloud, so both by direct inquiry and by inquiry through the Office of Naval Research in Pasadena, further information was sought.

Mr. E. E. Clary, Chief Scientist at Vandenberg, has very kindly provided unclassified information on this flight. The booster was destroyed at an altitude of 146,000 ft, almost directly overhead (but a bit south) of Vandenberg AFB at 1352 PST. As soon as this information was received, it appeared to offer the first solid clue as to the Flagstaff cloud's origin. The altitude at detonation was close to the photogrammetrically estimated cloud altitude, and the time of detonation made it necessary to consider very seriously the possibility that the Flagstaff cloud was some aftermath of the detonation. A crucial question was whether the time interval between the detonation over Vandenberg and the passage of the cloud over Flagstaff would match photogrammetrically estimated cloud-drift speed and/or other independent wind-speed observations.

Taking 1840 MST as the time of passage over Flagstaff, the 1452 MST (= 1352 PST) detonation time implies a hypothetical drift-time of 3 hours and 48 minutes. The airline distance to Vandenberg from Flagstaff is 510 miles, so the minimum mean drift speed required to associate these two events is very nearly 135 mph.

This required drift speed is substantially larger than Schley's roughly estimated 110 mph, and even further from the 77-95 mph estimated from the Lordsburg photos. Thus the agreement with respect to drift speed seemed rather poor, even though the height agreement between detonation and cloud seemed very encouraging. It was clearly necessary to seek further wind data, so inquiry was made concerning possible observational data from the Meteorological Rocket Network.

B. Rocket wind-data. The two nearest rocket-wind observation points happen to be rather well located to indicate winds along the trajectory that might have carried some explosion aftermath from Vandenberg to Flagstaff: One station is at Pt. Mugu, Calif., and the next nearest one is at White Sands, N. M. Queries were sent to both stations.

White Sands sent a Judi sounding rocket up at 0800MST on 28 February, about 10 hours before the Flagstaff passage. At 140,000 ft. the winds were 109 mph from WSW; at 150,000 ft. the winds were 97 mph from WSW. The following day, March 1, at 1215 MST, White Sands launched a Loki II sounding rocket that indicated winds of just over 90 mph from WSW at both 140,000 and 150,000 ft.

No sounding was available from Pt. Mugu on the 28th; but an Arcas launched at 0800 PST on March 1 indicated winds of 127 mph from the west at 140,000 ft. and 112 mph from the west at 150,000 at that time.

The rocket-sounding winds come tantalizingly close to fitting the hypothesis that the Flagstaff cloud was some byproduct of the Vandenberg detonation; yet the agreement is not quite close enough to be conclusive. The White Sands winds of the morning of the 28th seem significantly too low to match the required drift speed of 135 mph; but they agree rather well with the maximum cloud-drift speed estimated from the Lordsburg photos. It is regrettable that no Pt. Mugu winds were measured on the 28th. They would have shown whether the winds at that upwind location were enough higher than those at White Sands to imply a mean drift speed of around 135 mph. (A West Coast speed of something like 160 mph would be needed to yield the required mean of 135 mph, if we take the White Sands 0800 speed of 109 mph as typical of the stratosphere over Flagstaff near 140,000 to 150,000 ft. at 1840 MST on the 28th.) Although Mr. Willis Webb of the White Sands missile Range emphasized, in phone conversation on the problem, that variations above or below measured winds at times between observations might well approach 20 per cent of the measured values at these levels, it remains uncertain whether one may concluded that the Flagstaff cloud was due to the detonation at Vandenberg. It is necessary to seek still further cross-checks.

C. Unsettled questions. At this writing, further inquiries are being sent to the Chief Scientist of the Pacific Missile Range, to whom I have been directed by Vandenberg AFB for further information. It is hoped that phototheodolite movie records of the detonation may exist and may yield data on the initial drift speed and drift direction of the explosion cloud. Also, the initial configuration of the explosion cloud will be sought, along with information on possible presence of a side-explosion to the west of the main explosion. The latter item bears on the interesting problem of the "secondary cloud" west of the main one at Flagstaff. Many photos and still more letter-descriptions establish the presence of a smaller, roughly similar cloud some twenty miles west of the main ring. This cloud was definitely seen to form and to dissipate during the period of prominent visibility of the main cloud. Photos show it to have a more pear-shaped form than the main ring; and a short fish-tail formation existed at its northern extremity. It is difficult to see how a single detonation over Vandenberg could have also led to this secondary cloud. Mr. Clary, at Vandenberg, was fairly certain that no side explosions occurred; but this will be checked further.

In addition, information will be sought concerning the weight of liquid propellant still unburnt in the Thor at instant of detonation. This item of information will permit quantitative estimates to be made of the total water of combustion released in the explosion, as well as the heat release (for use in estimating buoyant circulation generation). These points, if they can be cleared up, may finally settle the question of whether the Flagstaff cloud can plausibly be identified as an aftermath of the Thor detonation over the California coast.

VI. Other observations.

A wholly unanticipated result of the now numerous appeals through press, radio, TV, and both scientific and popular magazines for more photos of the Flagstaff cloud has been the receipt of a very substantial number of reports (and a very few photos) of other roughly similar cloud phenomena. At first, these were confined to the Southwest and to the time period following immediately after the Flagstaff cloud appearance. But more recently, these reports have come in from other parts of the country, including now some seventeen reports for a night-luminous ring cloud seen in the central Atlantic seaboard area around 2100 EDT on May 23rd (possibly a Wallops Island tracer experiment - queries will shortly be made concerning this hypothesis). In addition, perhaps a dozen of the inevitable crackpot letters have been received as a result of Life's wide circulation; but there is little difficulty in distinguishing these letters from the far more numerous, straightforward letters reporting rather peculiar cloud sightings. Finally a few of the recent letters are obviously reports of persons who have seen either solar haloes, lunar coronae, or iridescent lenticular altocumulus clouds. The legitimate reports are under study.

VII. Concluding comments. The final objective of this study is to prepare a detailed scientific report for publication. The immediate task ahead is the photogrammetry. The decision as to how detailed a photogrammetric analysis to undertake on the 85 photos available for the Flagstaff stratospheric cloud will be made only after information can be obtained from the Pacific Missile Range. If it appears nearly certain that the cloud cannot be associated with the Vandenberg detonation, then the unprecedented height and configuration of the cloud will justify rather extensive photogrammetry. If it appears likely, on the other hand, that it was some side-effect of that detonation, it is still of considerable meteorological interest as a ready-made tracer experiment and as a telltale clue too certain interesting characteristics of the atmosphere in the little-known region of the stratopause, and hence will justify further analysis - but not as much analysis as if it is not attributable to the Thor-booster explosion.

In either event, the many persons who have assisted in the study and who may be wondering what is developing, should be informed that there will now be no further informal dittoed status reports of this sort. When a published report or reprint becomes available, copies will be sent to each person who has cooperated; but this may not occur now for a good many months. Hence, I want again to say thank you for your generous help in the study of this very interesting and unusual cloud.