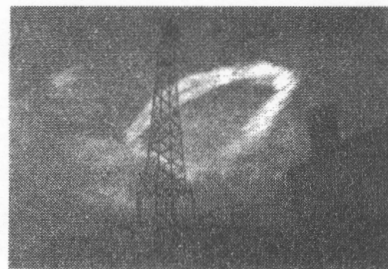


...And a High Cloud Ring of Mystery



Hovering like a giant's smoke ring, a great cloud appeared at sunset over Flagstaff, Ariz. last Feb. 28 and set off a continuing scientific mystery. Watchers struck by the cloud's odd shape and huge size, took pictures, like these four, at different times and from widely scattered locations in the state. Dr. James McDonald, a meteorologist at the Institute of Atmospheric Physics in Tucson, has been accumulating the pictures. Using them as the basis for trigonometric calculation, he has made a startling discovery that the cloud was at least 26 miles high and 30 miles across—"a lot higher and bigger," he says, "than a cloud should be." The circle was too high to be made by a jet plane, and so far as Dr. McDonald can determine, there were no rockets, rocket planes or bombs being tested nearby that day. He hopes anyone else with pictures will lend them to him, for he would like some more clues about the cloud 26 miles up—no water droplets exist at that height to make a cloud.



6:10 P.M., N.E. OF PRESCOTT



6:15 P.M., N. OF PHOENIX

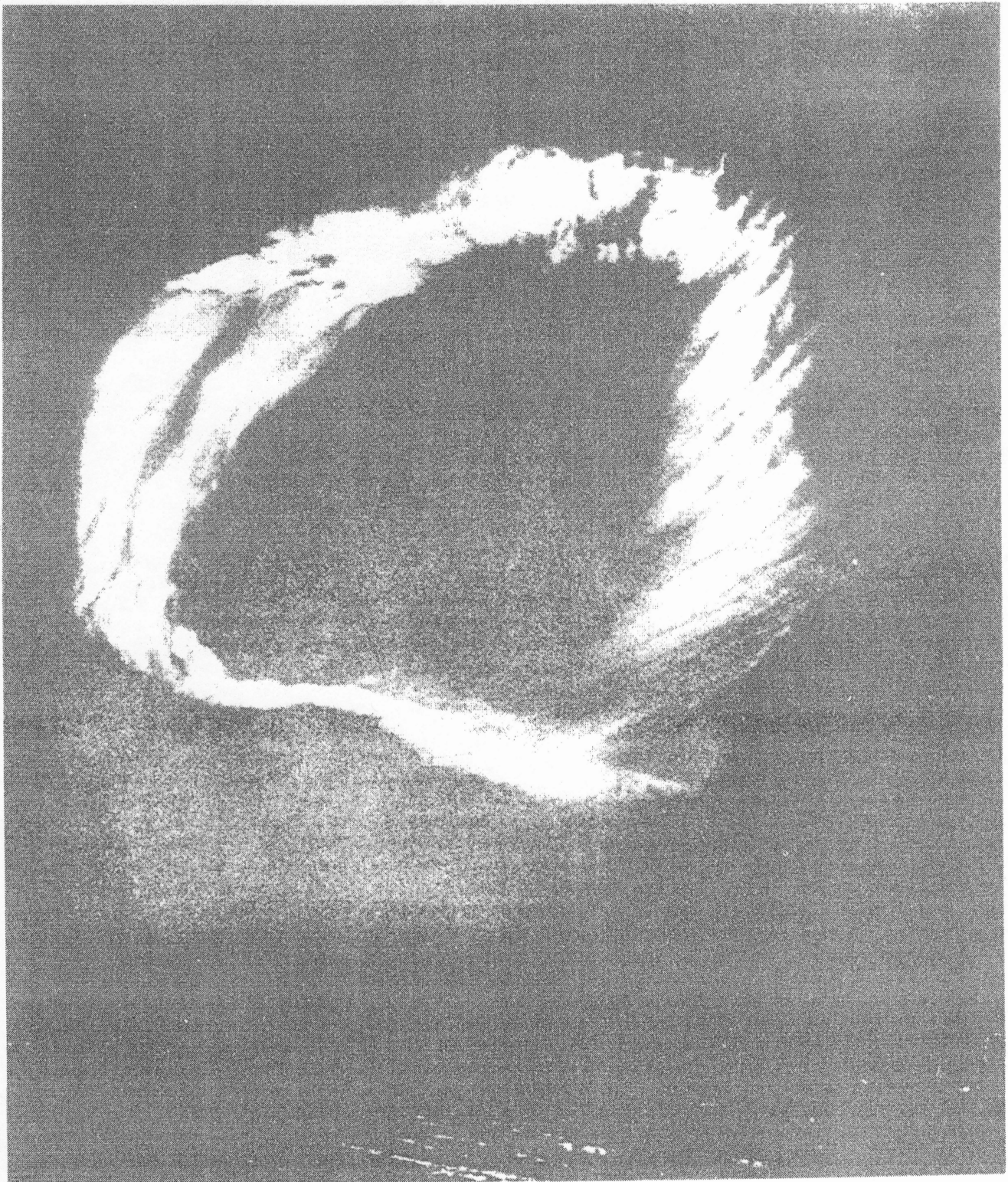


6:30 P.M., W.N.W. OF WINSLOW

Stratospheric Cloud over Northern Arizona

James E. McDonald

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STRATOSPHERIC CLOUD

Stratospheric Cloud over Northern Arizona

Abstract. *An unusual ring-shaped cloud was widely observed over northern Arizona near sunset on 28 February 1963. From a large number of observers' reports it is known to have appeared overhead near Flagstaff, Arizona. From initial computations based on four photos taken in Tucson, 190 miles south of the cloud, its altitude was approximately 35 kilometers. The most distant observation reported was made 280 miles from the cloud. The cloud remained sunlit for 28 minutes after local sunset. Iridescence was noted by many observers. Tentatively, the cloud may be regarded as similar to a nacreous cloud; but its unusually great height and unusually low latitude, plus its remarkable shape, suggest that it was a cloud of previously unrecorded type.*

Near sunset, on 28 February 1963, a cloud of unusual configuration and coloration was observed in widely scattered localities in Arizona and some surrounding states. The cloud took the form of a large oval ring (clear in the middle) with the long axis running north and south (Fig. 1 and cover photograph, this issue). It remained brightly illuminated well after the sun had set on high cirrus clouds to the west. From Tucson, 190 miles to the south, its angular elevation appeared to be about 6 degrees. A rough computation of its height, based on sunset geometry (1), made immediately after the cloud entered the earth's shadow, led me to appeal by press and radio for confirmatory reports in order to establish the approximate location and to secure descriptions from the largest possible number of other observers.

From approximately 150 reports, many communicated by persons well aware that they had seen a type of cloud unprecedented in years of skywatching, it was quickly established that the cloud lay overhead in the vicinity of Flagstaff, Arizona, that it exhibited iridescence of the sort associated with stratospheric nacreous clouds in the arctic (2, 3), and that its internal structure was very peculiar. To observers nearly underneath, the colors green and blue were visible, and a pinkish cast was noted at times. A fibrous texture, described by several independent observers as resembling a "wood grain" appearance, was present over much of its northern extent, but

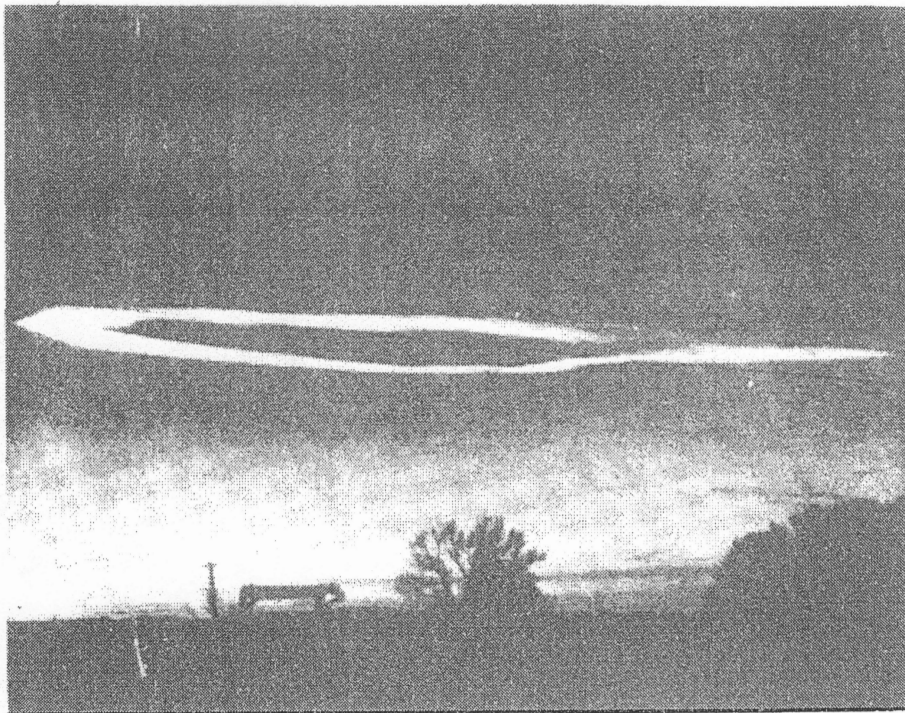


Fig. 1. Stratospheric cloud over Flagstaff, Arizona, from a point about 160 miles east-southeast, after sunset. The dark clouds in the west are cirrus clouds on which the sun has already set. [I. E. Daniels, Springerville, Arizona]

its southern end was denser and more cumuliform. Its overall shape was compared by some (ranchers) to a horse-shoe or a horsecollar if it was viewed from the south; from the north it appeared as a closed loop with a long thin trail that could be seen extending northward, from the oval, and several observers in that sector compared its shape with that of a "hangman's noose." The cloud was seen from distances as great as 280 miles (near Douglas, Arizona, and Albuquerque, New Mexico, respectively).

Many observers reported a second cloud off to the northwest of the main cloud, with shape very much like that of the main cloud, but only about a quarter as large. Correctness of these reports has been established from some of the first photographs that have come in from northern Arizona. The cloud was evidently moving generally southeastward, though visual reports are in some conflict on this point; this point can only be resolved from further studies by triangulation.

By fortunate coincidence, the cloud appeared within a few tens of miles of the U.S. Weather Bureau radiosonde station at Winslow, Arizona, and a high-altitude sounding had been completed there only an hour before the appearance of the cloud. A jet stream lay almost directly under the cloud and over Flagstaff, and there were peak

winds of 98 knots from the northwest occurring over Winslow at an altitude of about 11 kilometers. The radiosonde run terminated at the 13-millibar level of atmospheric pressure (about 29 km), where the temperature was -46°C . There was very little direction shear in the Winslow wind sounding, a condition known to favor formation of mountain waves and believed to be conducive to nacreous clouds, at least in Scandinavia (2). It is possible, therefore, that the San Francisco Peaks just north of Flagstaff disturbed the flow so that wave motion was set up in the stratosphere, but this remains a conjecture, pending further study of reports of first appearance. Whereas some recent studies (4) suggest strong local stratospheric cooling as a prerequisite for the formation of nacreous clouds, the sounding at Winslow showed little departure from average temperature conditions in the lower and middle stratosphere.

Photogrammetric analysis of the four photographs known to have been taken in the Tucson area have yielded elevation angles of the near point ranging from 5.9 to 6.2 degrees. Because the exact range to the nearest point of the cloud is not yet known to better than about 10 or 15 miles in 190 miles, the exact height cannot yet be determined. However, the cited elevation angles plus allowance for earth curvature give

a cloud height of 35 kilometers, possibly a bit higher if the range to the near point proves to be greater than 190 miles. This height is distinctly greater than that of reported Scandinavian nacreous clouds. Photogrammetric heights obtained over many years by Størmer and others (2, 3) are no higher than 30 kilometers, and the majority lie between 22 and 28 kilometers.

The estimated height of 35 kilometers rules out the possibility that the Flagstaff cloud could have been the condensation trail from a jet plane. The present American altitude record, made under the most favorable conditions directly above the home field by a Lockheed F-104 in 1959, is 103,395 feet (31.6 kilometers). Perhaps more conclusive is the fact that the upper limit of height for possible contrail formation (5) as indicated by the sounding from Winslow was just under 24 kilometers at the time of the cloud's appearance.

These preliminary indications mark the Flagstaff cloud of 28 February as a most unusual phenomenon of considerable meteorological interest. Requests for photographs, still being made at time of this writing, have already brought promises of photographs from a total of 16 sites reasonably well dispersed around Arizona, so fairly precise data on the cloud's height, shape, and dimensions should be obtainable by triangulation. A conflict between heights estimated from the Tucson photos and from sunset geometry is under study (the indicated height based on available reports of fadeout time is about 25 kilometers). Premature fadeout may have been due to cirrus clouds between the cloud and the ray-tangency point, computed to lie at or very near Los Angeles.

The hydrodynamics of the field of vertical motion that produced such a toroidal cloud form are very puzzling. Present estimates give the closed oval a length of about 60 kilometers and a width of about 30 kilometers, with a ring cross section of perhaps 3 to 4 kilometers in the horizontal. I am not aware that a cloud of such form and size has been observed at any level within the atmosphere before. Interesting questions about the source of the requisite water vapor are posed by its unprecedented altitude (6).

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References and Notes

1. S. K. Mitra, *The Upper Atmosphere* (Asiatic Society, Calcutta, ed. 2, 1952).
2. E. Hesstvedt, *Geofys. Publikasjoner Norske Videnskaps Akad. Oslo* 20, No. 10 (1959).
3. A. Y. Driving, *Bull. Acad. Sci. U.S.S.R. Geophys. Ser. 3, English Transl.* (1959), pp. 279-286.
4. Y. Gotaas, *Geofys. Publikasjoner Norske Videnskaps Akad. Oslo* 22, No. 4 (1961); A. Y. Driving and A. I. Smirnova, *Bull. Acad. Sci. U.S.S.R. Geophys. Ser. 3, Eng. Transl.* (1958), pp. 187-191.
5. H. Appleman, *Bull. Am. Meteorol. Soc.* 34, 14 (1953).
6. I thank Leon Salanave for alerting me to the cloud when it became visible in the Tucson sky and for further technical assistance, and I. E. Daniels and C. E. Peterson for permission to reproduce their photographs. The cooperation of the numerous Arizonans submitting reports is gratefully acknowledged. Supported by the Office of Naval Research under contract NR 082-164.

20 March 1963

Cloud-Ring in the Upper Stratosphere

JAMES E. McDONALD, *Institute of Atmospheric Physics,
University of Arizona, Tucson*

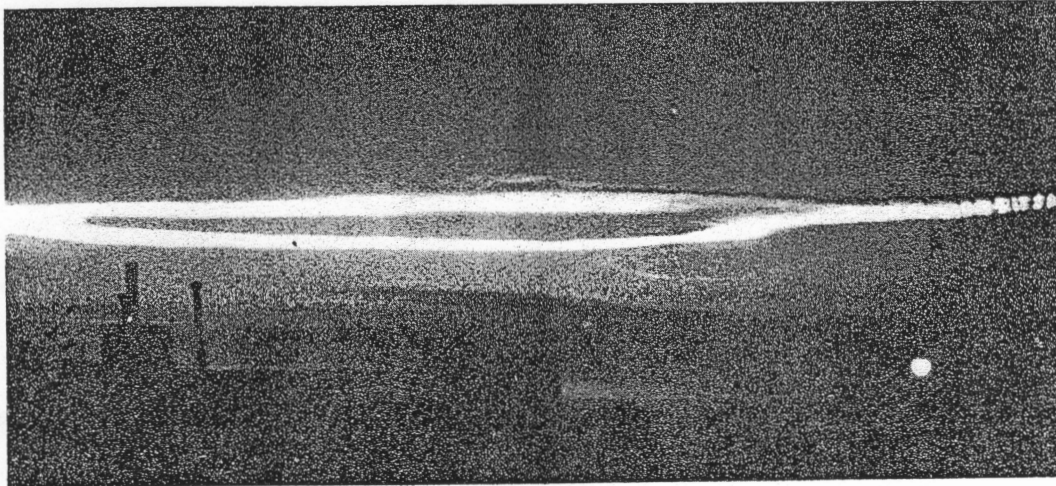
AT sunset on 28 February 1963, observers scattered over an area of nearly two hundred thousand square miles in the Southwest witnessed a strikingly beautiful cloud display. After three months of effort to determine just what it was that caught their eyes, I am still not sure myself, though the number of pertinent clues has now grown fairly large.

Many persons at first thought it just a large contrail, as I did when first viewing it from Tucson. But the clue to its extremely great height came quickly as the setting sun's rays left darkening high cirrus clouds far to the west (!), while the ring still shone with a beautiful luminescent silvery cast. From quick computations based on the sunset geometry (the ring went dark at about 1850 MST), I estimated its altitude at over 30 km, and immediately put out an appeal through press and radio for observers' reports. In all, some 200 reports were ultimately received; and subsequent press appeals for photos has led to a total of 85 photos from 35 different localities for photogrammetry use.

It is now known that the ring lay at an altitude of 43 km above sea level (to within a present uncertainty of only about one kilometer), which is far higher than the 20–30 km range of Arctic nacreous clouds. It was nearly overhead at Flagstaff, Arizona, at about 1840 MST, and many excellent photos showing the cloud's unprecedented variety of internal wave structures have been received from persons in that area. Its north-south extent was over 50 miles, and its east-west width was around 30 miles. Like a huge doughnut, its center was open.

Although, to most observers in Arizona, its color appeared silvery white in the twilight sky, most observers in New Mexico reported iridescence. It was seen in Arizona, Colorado, New Mexico, and even northern Mexico (Juarez, about 380 miles from the southern tip of the cloud-ring). In one report after another, I read the observer's emphatic remarks to the effect that, in a lifetime of cloud-watching, he had never before seen a cloud as beautiful as this one.

(Continued on page 148)



The ring-cloud over Flagstaff is flattened by perspective into a long thin loop in this photo by Lynne E. Cobble, taken at Albuquerque, N. M., some 280 miles from the cloud. Intense low-angle forward-scattering by the cloud particles (presumed to be water or ice) creates strong contrast against the twilight sky. Sun had set at Albuquerque almost a half hour before this photo was made at 1840 MST. Kodak Retina Reflex camera F4 1/8th of sec. with 135mm telephoto lens. Photo courtesy Sgt. Arthur A. Francis, Kirtland AFB, who is making a study of the phenomenon.

Stratospheric Cloud

(Continued from page 99)

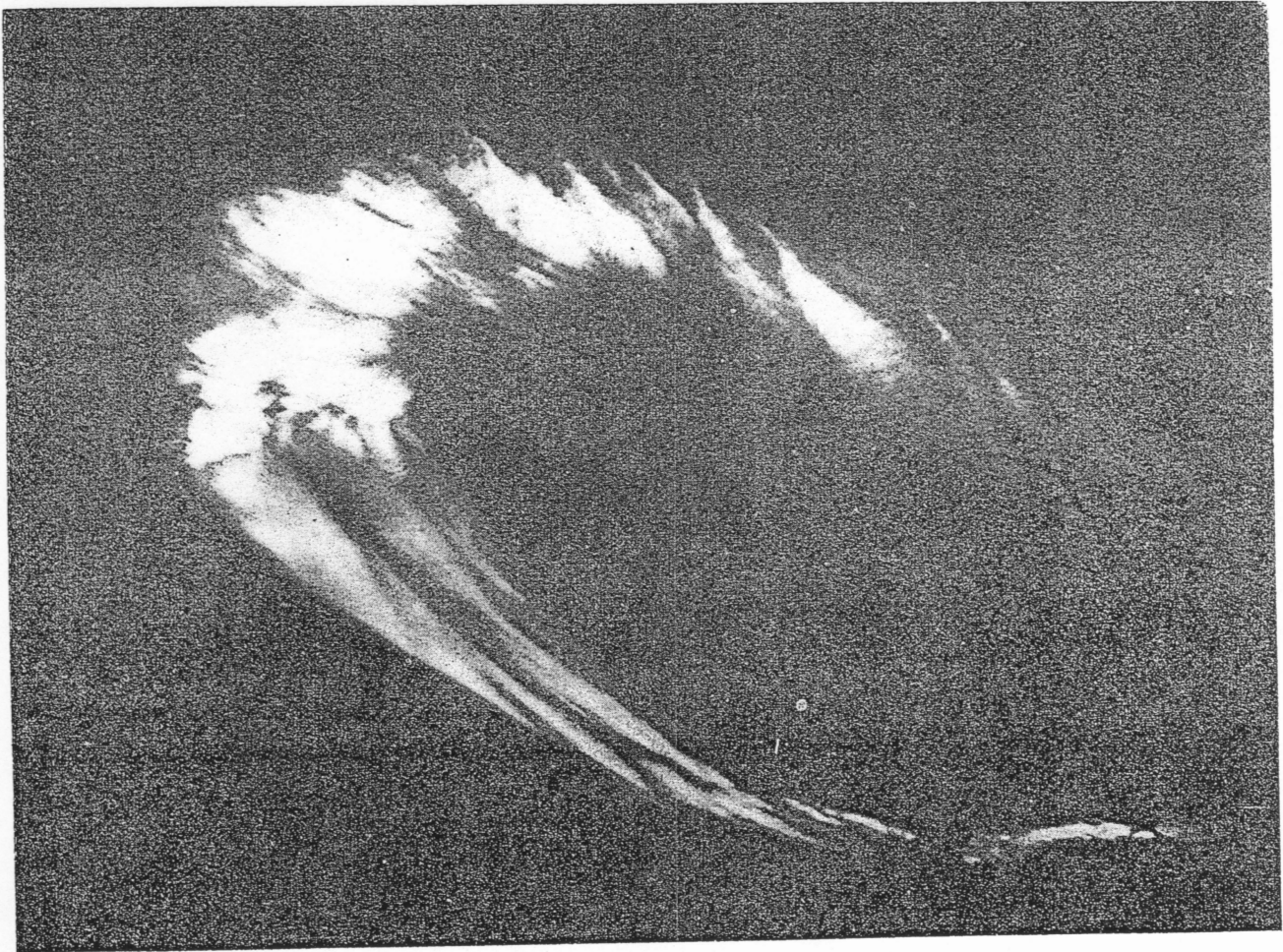
What was it? I'm still trying to answer that. It was far above the upper limit of contrail formation. No X-15 flights were made that day, and it lay well above my thermodynamically estimated upper limit of 27 km for the maximum altitude at which the ammonia and liquid oxygen rocket motors of an X-15 could form contrails. No Nevada Test Site activity occurred that day, and nothing else turned up from inquiries at a number of other Southwest defense bases. However, a brief press account of the intentional destruction of a rocket over Vandenberg AFB, Calif., that day led to inquiries that are still continuing at this writing (6/4/63).

The Thor booster of a military satellite-launch was detonated at 44 km at 1352 PST almost directly over Vandenberg AFB. To account for a drift of 510 miles to Flagstaff in time to have lowered the jaws of Flagstaffians looking straight up at 1840 MST, calls for a mean drift speed of 135 mph. Inquiries at the White Sands and the Pt. Mugu Missile

ranges have yielded meteorological rocket winds for times about a half-day before and after the detonation event. The rocket winds are generally a bit too low to fit well; however, the Pt. Mugu 140,000-ft winds the following morning were 127 mph from the west. My own photogrammetrically estimated cloud-drift speeds fall below 95 mph when the cloud was over northern Arizona. I am hoping that phototheodolite films from the Pacific Missile Range may finally fill the gap in wind data by showing the initial drift speed and direction of the explosion debris itself. A number of other related questions are still under study.

The cloud lay right at the base of the "region of exclusion" for water drops and ice particles in that layer (about 42 to 65 kms, on the average), where temperatures are so warm that saturation vapor pressures exceed ambient pressures. If this was, in fact, the aftermath of the Thor explosion, persistence of a circulation and of condensate for nearly four hours of downwind drift will be of considerable meteorological interest. If it was not due to the explosion, then the mystery will be back where it started at sunset on 28 February.

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STRATOSPHERIC CLOUD OVER ARIZONA

1963 JAVELINA HUNT REGULATIONS

T-12, JAVELINA HUNT REGULATIONS ARIZONA GAME & FISH DEPARTMENT

SEASON: March 1 - March 10, 1963, inclusive

LEGAL ANIMAL: One javelina, any age, either sex.

BAG & POSSESSION LIMIT: One javelina, See Commission Order P-36

OPEN AREA: Statewide, EXCEPT Three Bar, Santa Rita, Tucson Mountain, Robbins Butte, and Arlington Wildlife Areas, and Game Management Unit 20, and posted portions of the Cibola and Topock Wildlife Areas.

A valid Class F or G license and valid javelina tag must be in possession of any person hunting javelina.

FORT HUACHUCA MILITARY RESERVATION SPECIAL JAVELINA HUNT:

SEASON: March 1 - March 10, 1963, inclusive.

NUMBER OF PERMITS: 125

DESCRIPTION OF AREA:

The Fort Huachuca Military Reservation lying within Game Management Unit 35.

The Fort Huachuca Military Reservation shall be open only to hunting by properly licensed civilian and military personnel attached to Fort Huachuca.

Hunters will be selected by drawing with the numbers of civilian and military hunters to be determined on the basis of the ratio of civilian to military applications. Application blanks will be available beginning January 28, 1963, at Fort Huachuca. Applications will be received at Fort Huachuca on or after January 28, 1963, and before noon on February 15, 1963, and quota for the hunt will be filled by public drawing at Fort Huachuca in the presence of Arizona Game and Fish Department personnel on February 15, 1963. Permits will not be valid until countersigned by the Commanding General, or his representative, at the time and place designated by him.

All hunters must personally check into and out of the area through a checking station as designated by the Commanding General.