THE FIREBALL OF DECEMBER 9, 1965—PART I

CALCULATION OF THE TRAJECTORY AND ORBIT BY PHOTOGRAPHIC TRIANGULATION OF THE TRAIN

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Abstract

Photographs, taken from two locations, of the train of the fireball of December 9, 1965, were used in determining the trajectory and orbit of the meteorite. Although the velocity of the object is uncertain, an orbit of direct motion and moderate inclination and eccentricity was found.

Sommaire

Des photographies, prises à deux stations, de la trainée du météore du 9 décembre 1965, ont été utilisées pour déterminer la trajectoire et l'orbite du météorite. Bien que la vitesse de l'objet soit incertaine, on déduit une orbite directe, d'inclinaison et d'excentricité modérée.

At about 4:43 p.m. E.S.T. on Thursday, December 9, 1965 a brilliant fireball was observed over a wide area, including portions of at least six states and Ontario, centred north of the western end of Lake Erie. The usual rash of early reports gave "landing sites" for the object ranging from western Michigan to Pennsylvania. In response to news media requests, over 150 descriptions of the event were received. Standardized questionnaire forms were sent back to 107 individuals, of whom 66 returned completed forms.

A preliminary analysis of these data indicated that the meteorite had been moving in a generally north-easterly direction, disappearing at a point over land some 15 miles south-east of Windsor. A majority of the observers gave a duration of 3 to 4 seconds for the visual phenomenon. Judging from the numerous descriptions of the event, it is estimated that, as seen from Detroit, Michigan, the fireball had an apparent magnitude of at least −15. Loud sonic booms were heard in the Detroit-Windsor region at intervals after the visual sighting. According to various observers the dust train, which was later found to have been photographed, persisted for some 30 minutes or longer. A "puff of smoke" was visible at the terminal end of the train, where reports indicated the major burst occurred. The visible fireball ended at this point, but several observers reported that some material apparently continued beyond, along the

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original trajectory. This was subsequently confirmed by the photographs (figure 1). The reported times of the event clustered around 4:43 p.m.

FIG. 1—Photograph of the fireball train of December 9, 1965, taken by Lowell Wright at Orchard Lake, Michigan, within a few seconds of the disappearance of the fireball.

E.S.T. (21:43 U.T.) to the nearest minute. It was later found that the Geophysics Laboratory of the University of Michigan, at Willow Run Airport near Ypsilanti, Michigan, recorded a shock phenomenon on a seismograph shortly after the fireball event. The assumption that this pulse was generated at the apparent burst point near the end of the trajectory (allowing for the variations of the speed of sound with altitude), combined with subsequently-determined location of the burst point in the atmosphere, permitted calculating the time of the fireball as 21 hours 43 minutes 00 seconds, to within about 10 seconds.

Contact was made with Dr. J. A. V. Douglas of the Geological Survey of Canada, and Mr. Henry Lee of The Royal Astronomical Society of Canada through Dr. Peter Millman of the National Research Council of Canada. One of the authors (V. D. C.) spent some time in the area of possible meteorite fall confirming the trajectory and initiating the search for meteorites. Douglas and Lee carried on more extensive investigation

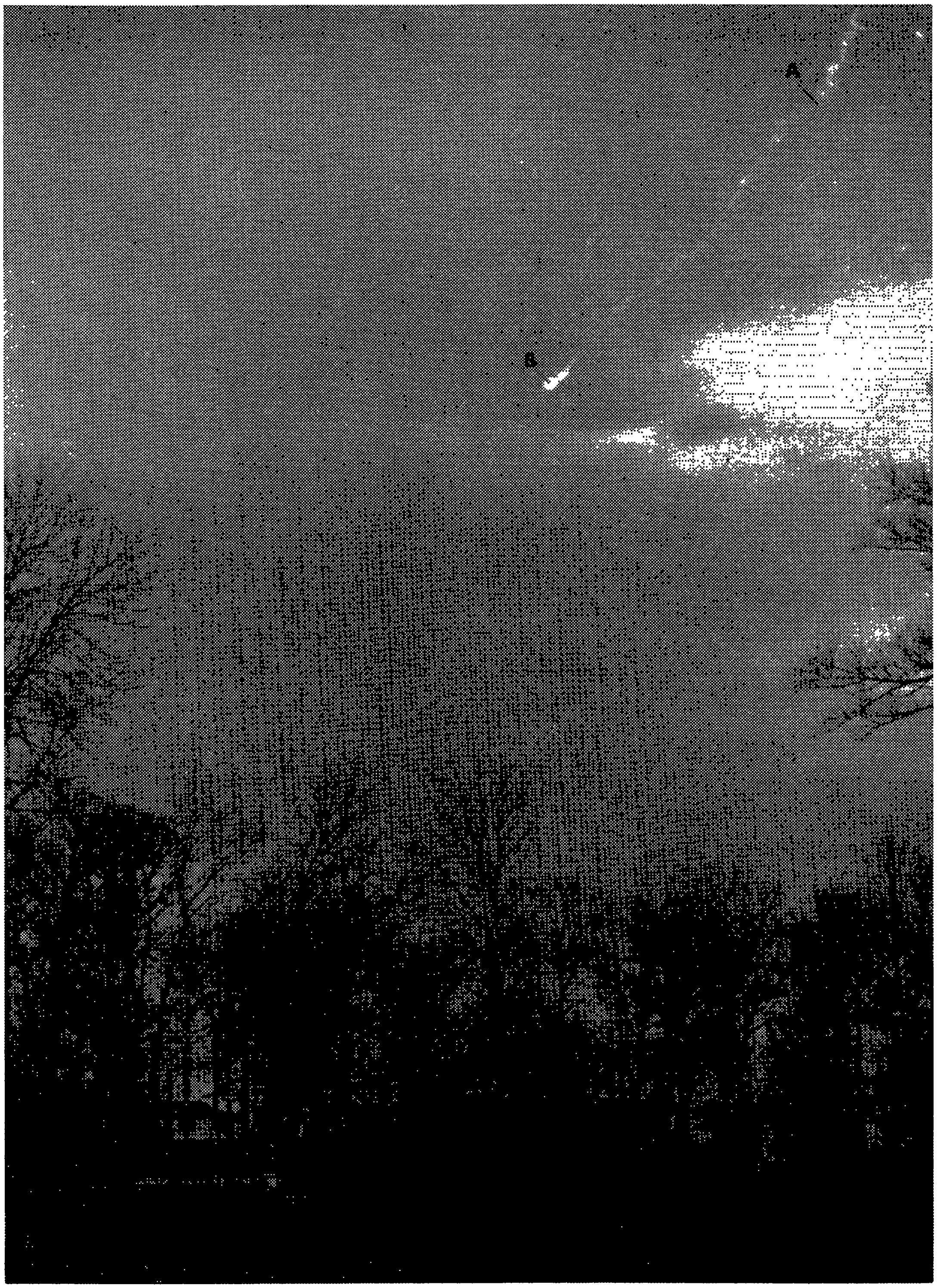

FIG. 2—Wright's second photograph of the train. Points *A* and *B* were used in calculation of the trajectory.

of visual sightings, audible phenomena and meteorite search ("The Fireball of December 9, 1965—Part II"). To date no meteorites have been found.

One person responding to the request for reports was Mr. Lowell Wright of Berkeley, Michigan, who was taking sunset pictures at Orchard Lake,

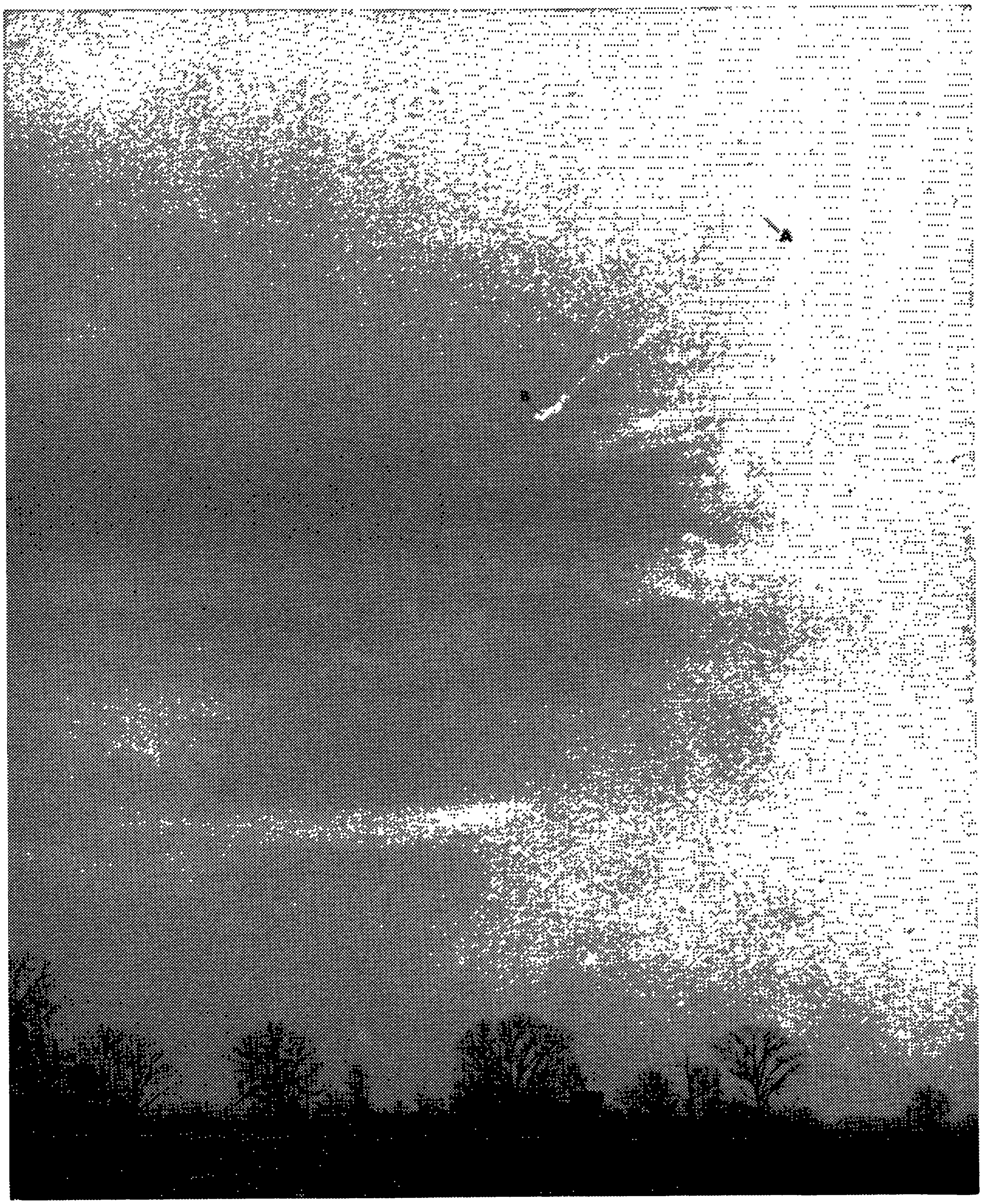

FIG. 3—Photograph by Richard Champine of the fireball train. Compare points *A* and *B* with the corresponding ones in figure 2.

about 5 miles south-west of Pontiac, Michigan, as the event occurred. He obtained two photographs of the train (figures 1 and 2), the second of which he estimates was taken within 15 seconds of the event. It was later determined that Mr. Richard Champine of Royal Oak, Michigan, had made a series of four photographs of the train from a point about two miles east of Pontiac, Michigan, the first of which (figure 3) was taken approximately 45 seconds after the visual phenomenon. The four Champine photographs cover a span of about 80 seconds, and reveal that the total drift of the cloud was minimal, although disintegration of the train is evident. The photographs shown in figures 2 and 3 were used in the calculation of the trajectory of the meteorite.

Two points along the train, identifiable on both photographs, were selected as triangulation points (Points *A* and *B* in figures 2 and 3). Azimuths and altitudes of various landmarks seen on the photographs were obtained by surveying at each site, and were used in determining

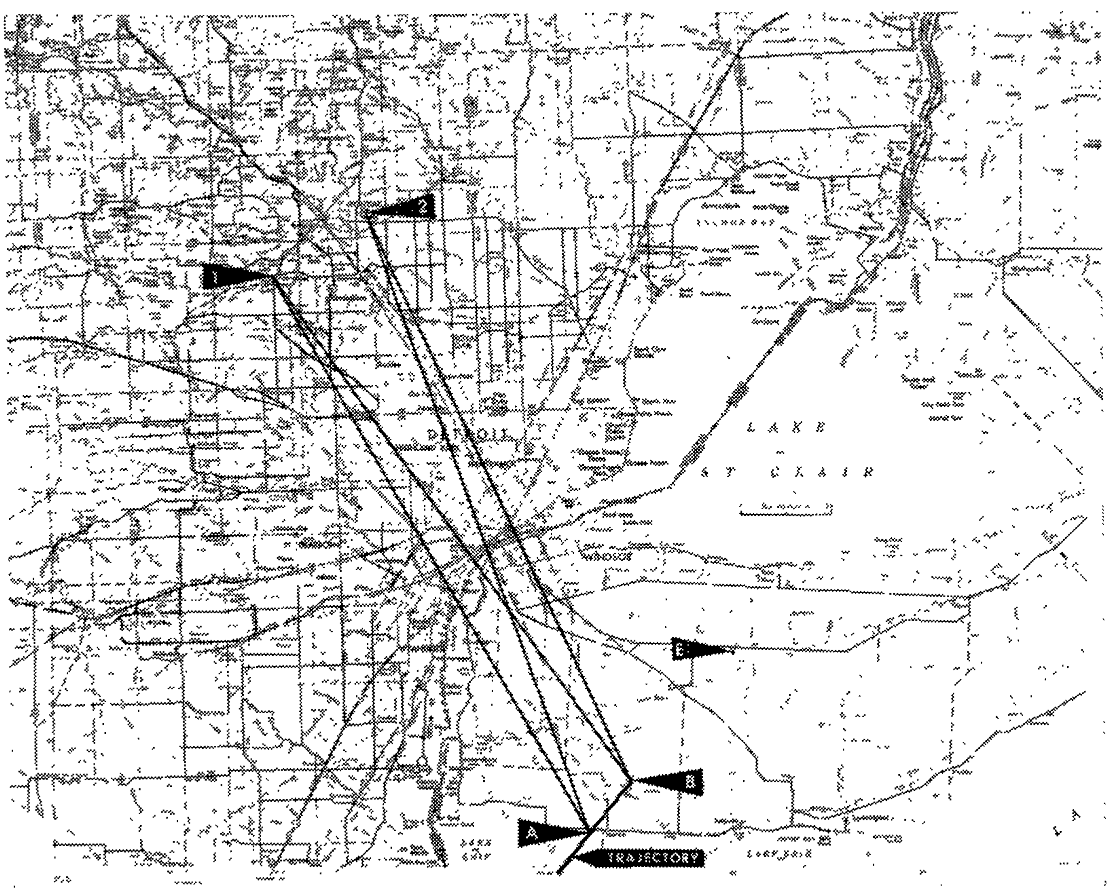

FIG. 4—Triangulation of points *A* and *B* from the photographs shown in figures 2 and 3. Locations 1 and 2 are the sites of the photographers Wright and Champine respectively. Point *E* is the earth point.

the scale factor for each photograph. Observations of the sun were also made to determine the magnetic declination at each location. Graphical plotting of these data on a map of the area gave the latitude and longitude of the points on the earth beneath A and B (figure 4). The altitudes obtained from the photographs then permitted calculation of the heights of the points. Point A was calculated to be 22.9 km. above the ground at longitude 82°53.1′ west, latitude 42°5.1′ north. Point B, the burst point, was 32.2 km. above ground at longitude 82°56.4′ west, latitude 42°2.0′ north. The trajectory made an angle of 52 degrees with the horizontal, the earth-point (trajectory extended to the ground) was at longitude 82°44.9′ west, latitude 42°12.6′ north, and the azimuth of flight was N 39° E.

The velocity of the meteorite as it passed through the earth's atmosphere is uncertain. Relying on the duration estimates of Messrs. Wright and Champine, who in the opinion of the writers were best qualified to judge, an apparent velocity of 14.5 km/sec was adopted as the value to be used in the orbit calculation.

The orbital elements were calculated by well known procedures (Wylie 1939). On the assumption that the apparent velocity was 14.5 km/sec, the calculated elements are:

Geocentric velocity = 9.3 km/sec
Heliocentric velocity = 36.2 km/sec
Semi-major axis, a = 1.81 AU
Eccentricity, e = 0.483
Inclination, i = 6.0°
Longitude of ascending node, Ω = 257.6°
Argument of perihelion, ω = 147.9°
Period = 2.43 years.

Figure 5 shows the relationship of this orbit to the orbits of the inner planets. In view of the uncertainty in the apparent velocity, it is noted that an increase or decrease of, say, 20 per cent in this velocity would change some of the orbital elements considerably. A velocity 20 per cent lower than that used to calculate the above orbit yields $e = 0.13$, $a = 1.1$ AU, and $i = 1°$. A 20 per cent increase in the velocity makes $e = 0.72$, $a = 3.3$ AU, and $i = 9°$. In both cases, the argument of perihelion is changed only slightly, the line of nodes is unchanged, and the orbit is direct.

At the present time, there is considerable disagreement concerning the origin of meteorites (Anders 1964, Opik 1966). In any theory, however, actual orbits determined from observed fireballs must play a significant part. In spite of the uncertainty of the velocity in the above calculations,

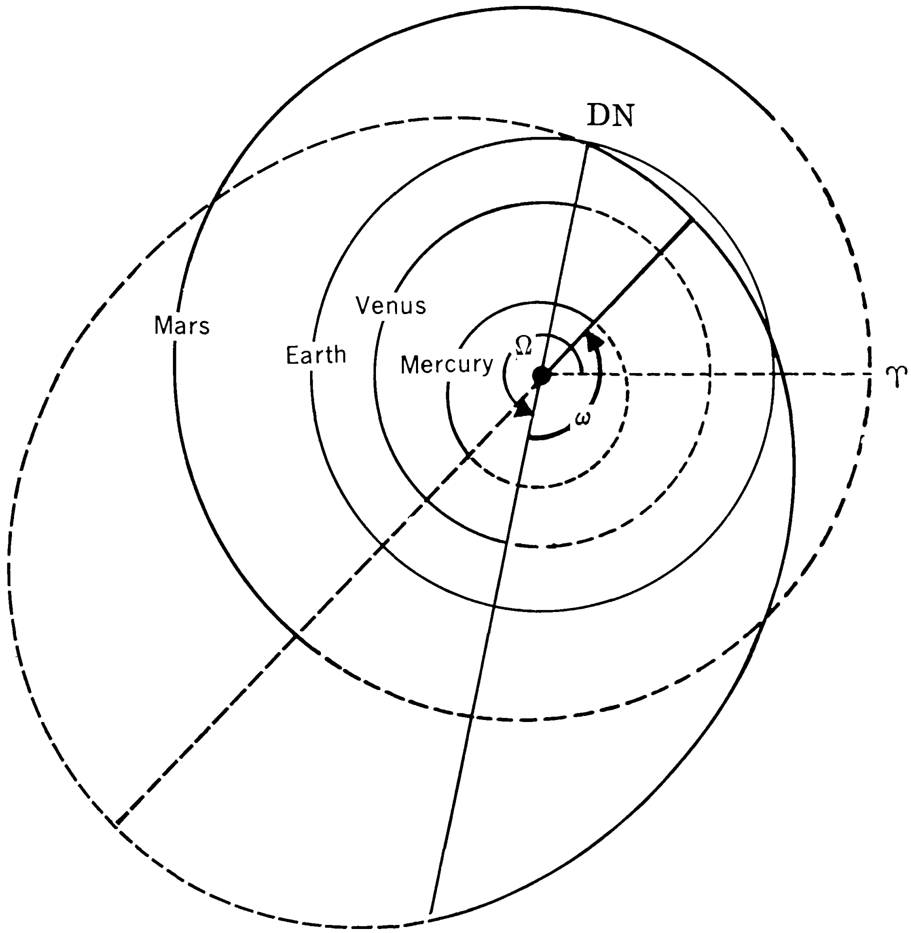

FIG. 5—The calculated orbit in relation to the orbits of the inner planets. *DN* marks the descending node.

the photographically-determined data are probably more reliable than those generally available from visual sighting alone.

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REFERENCES

Anders, E. 1964, *Space Sci. Rev.*, **3**, 685.
Opik, E. J. 1966, *Advances in Astronomy and Astrophysics*, ed. Z. Kopal, **4**, 301.
Wylie, C. C. 1939, *Pop. Ast.*, **39**, 425, 478, 549.