Fall of the Sputnik I Rocket

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There has been considerable interest in the matter of determining the probable point of impact of artificial satellites, (See Science, 126, No. 3287, December 27, 1957). We are conducting a study of the behavior of satellites as they re-enter the atmosphere during the final phase of their lifetimes, and in this connection we have examined the data on Satellite 1957 Alpha 1, the carrier rocket which accompanied Sputnik I.

Our calculations lead us to the conclusion that 1957 Alpha 1 fell on December 1 at 0846 GMT, approximately 8 hours after the last radar observation made on it in the United States. We place the probable point of impact at latitude 45° N. and longitude 106° E., in Outer Mongolia. The result of our investigation is shown in Figure 1, which represents the trajectory of 1957 Alpha 1 during its final pass over the northern hemisphere. The probable impact point is marked by a circle in Figure 1, and the uncertainty in the impact point by heavy lines to either side of this circle.

The analysis is based on several observations of the altitude of the satellite during the last 5 days of its lifetime. These altitudes were deduced from radar data on 1957 Alpha 1 obtained by: (a) the Lincoln Laboratory[1] on November 27 at 2153 GMT, November 29 at 2137 GMT, and

[1] G. H. Pettengill, private communication.

November 30 at 1944 GM and 2114 GMT; (b) the Stanford Research Institute[2] on December 1 at 0011 GMT; and (c) the staff of the Royal Radar Establishment[3] at Malvern, England on December 1 at 0828 GMT.

The altitudes obtained from these radar sightings are indicated in Figure 2. Figure 2 also shows the calculated altitudes, determined by us from a numerical integration of the satellite equations of motion starting with orbital data provided by the Smithsonian Astrophysical Observatory for the date of November 11, 1957. The calculated altitudes in Figure 2 are seen to be in good agreement with the observed altitudes for all passes.

The penultimate measurement shown in Figure 2 was taken on the Stanford radar during the final pass of the satellite over the United States. The last measurement in Figure 2 is that of the RRE radar at Malvern, obtained, as already noted, at 0828 GMT. It is interesting to note that even if both of these data are omitted, the comparison of the remaining observations with our calculated altitudes indicates that the satellite could not have fallen during its last pass over the continental United States, nor in fact for several passes thereafter. For if we assume the last pass in the lifetime of the satellite to be that in which it crossed the western United States, the calculated altitudes then fall on the dashed curve of Figure 2. The differences between this curve and the data are well outside the probable errors for the observations. In our view Figure 2 provides conclusive evidence that the satellite continued on for approximately 8 hours beyond the pass over the west coast of the United States.

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[2]A. M. Peterson and W. E. Jaye, private communication.

[3]J. S. Hey and V. A. Hughes, private communication.

The last datum point in Figure 2 is an altitude of 71 miles, obtained by the RRE radar. This observation is critical for the unambiguous determination of the impact point. An altitude as low as 71 miles indicates that at the time of the passage over Malvern the rocket had entered on the final dive of its re-entry into the atmosphere. The detailed numerical integrations then indicate that the rocket continued on past Malvern for 64° in the plane of the orbit before striking the Earth. This figure of 64° is subject to an uncertainty of $\pm 15^{\circ}$, corresponding to the probable error in the altitude of the RRE observations, and to an uncertainty of $\pm 15^{\circ}$, corresponding to an assumed variation in the drag coefficient by a factor of 2. The combined uncertainty is shown by the heavy line in Figure 1, as mentioned above.

In the final phase of the re-entry the rocket probably disintegrated into elements of differing drag coefficient, whose impacts would be strewn over an arc length of the satellite trajectory approximately equal to the uncertainty in impact shown in Figure 1.

Figure 1. Polar projection of the northern hemisphere showing the trajectory of Satellite 1957 Alpha 1 during its final pass. The calculated impact point is indicated by a circle at latitude 45° N. and longitude 106° E. The probable error in the impact point due to uncertainties in (i) the altitude over Malvern, England and (ii) the drag coefficient is indicated with heavy lines to either side of this circle.

Figure 2. Comparison of observed and calculated altitudes during the final days of Satellite 1957 Alpha 1: Lincoln Laboratory; Stanford Research Institute; Royal Radar Establishment (Malvern, England). The solid curve indicates the calculated altitudes. The dashed curve represents the calculated altitudes on the assumption that the satellite fell during its last pass over the United States.

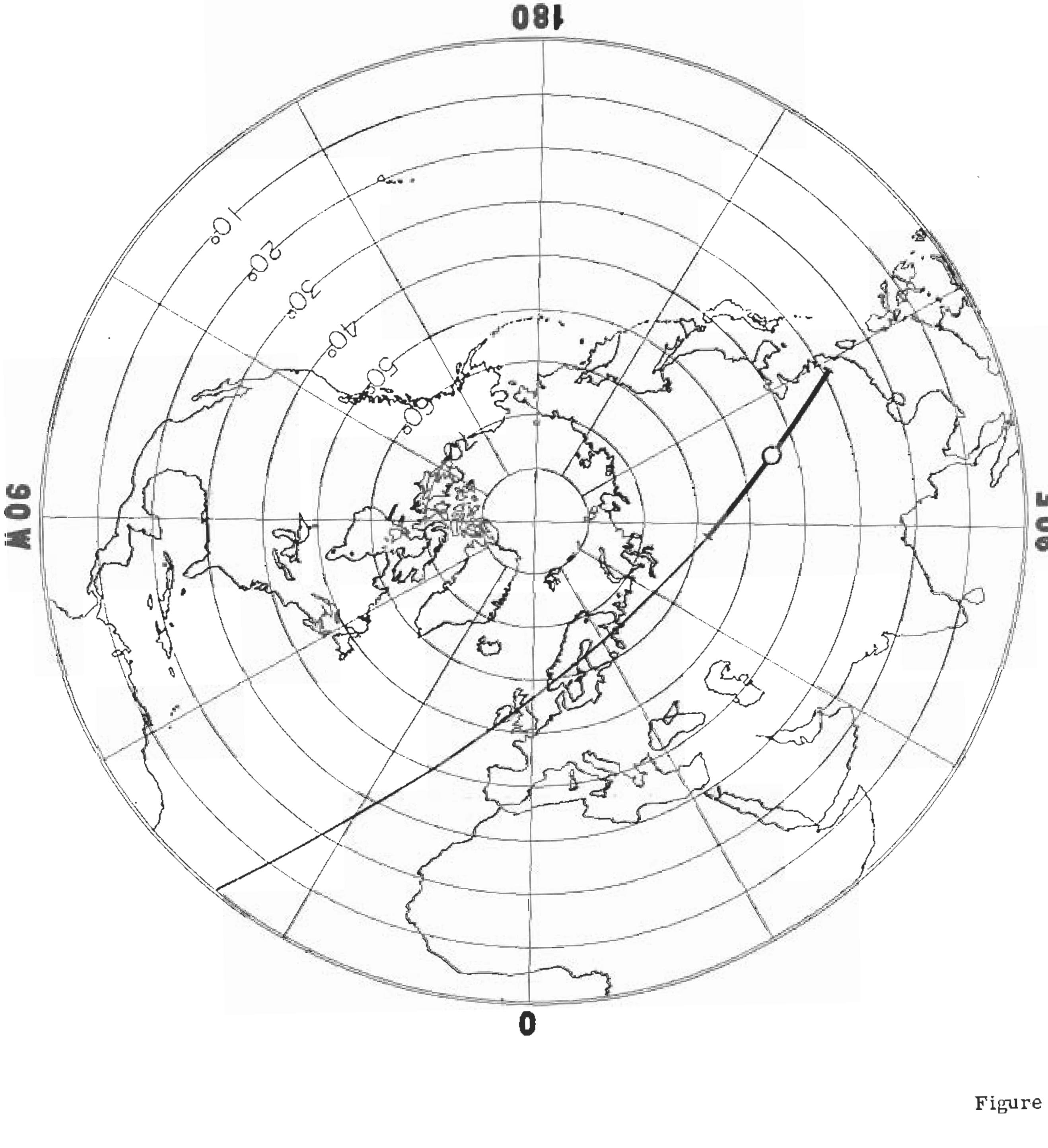

Figure 1

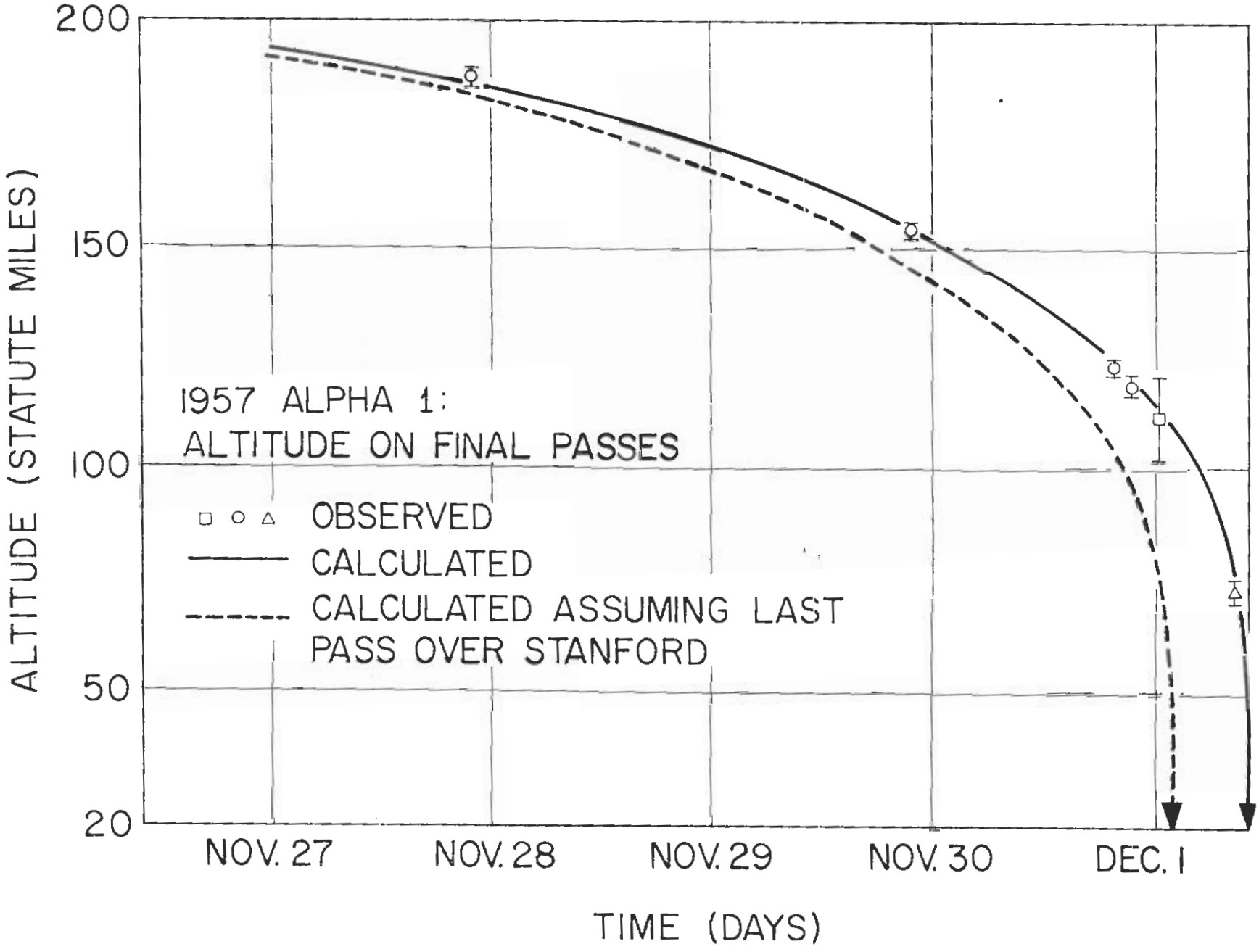
200
150
100
50
20
ALTITUDE (STATUTE MILES)
1957 ALPHA 1:
ALTITUDE ON FINAL PASSES
OBSERVED
CALCULATED
CALCULATED ASSUMING LAST PASS OVER STANFORD
NOV. 27
NOV. 28
NOV. 29
NOV. 30
DEC. 1
TIME (DAYS)

Figure 2