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ROYAL AIRCRAFT ESTABLISHMENT

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SUMMARY

At 17 h 57 m U.T. on 20 November 1968, Cosmos 253 rocket (1968-102B) re-entered the atmosphere over England after a week in orbit. The decay was widely observed, and the reports received have been analysed to determine the track and height. The track was from Manchester (height 80 km) to Canterbury (height 45 km), with the final burnout area south-east of Dover.

This paper is a slightly improved version of that published in Nature (211, 130-2, 11 January 1969).

The first widely observed re-entry of an artificial satellite into the atmosphere occurred over ten years ago, when Sputnik 2 met a fiery end over the Caribbean[1] on 14 April 1958. In the intervening years there have been more than 2000 re-entries of satellites and other catalogued pieces of space debris, of which more than fifty have been observed, most often by the flight crews of airliners[2]. The first re-entry to be seen by large numbers of people in Britain occurred on the evening of 20 November 1968, when the satellite 1968-102B, the final-stage rocket that had put Cosmos 253 into orbit 7 days before, burnt out over Southern England at 17 h 57 m U.T. (18 h 57 m B.S.T.).

It is difficult to predict the exact re-entry point of a decaying satellite more than an hour or two ahead, and regular satellite observers, after many fruitless vigils, have learnt to treat decay predictions with scepticism. However, the decay time of Cosmos 253 rocket was correctly predicted several hours beforehand both by the British prediction centre at the Radio and Space Research Station, Slough, and by the United States Air Force, whose prediction was telegraphed by the Moonwatch Division of the Smithsonian Astrophysical Observatory to those British observers who are in the Moonwatch network. Unfortunately, most of Britain was covered by cloud on the evening of 20 November, and the majority of the regular observers, including one of the authors of this paper (D.G.K.), saw nothing because of cloud. The other two authors were watching for the re-entry and observed it, though with some interference from cloud. We have analysed these observations and 83 other reports received at the Royal Greenwich Observatory, Herstmonceux, the Radio and Space Research Station and the Royal Aircraft Establishment. These sightings were mostly from south-east England, but five reports came from the crews of airliners and one from Scotland. Unfortunately most witnesses were so impressed by the visual appearance of the object that they failed to note its exact position in the sky, and few of the observations can be regarded as accurate to better than $\pm 5^{\circ}$.

The track of the decaying satellite over Britain, obtained from the position of the orbital plane as given in the final United States Air Force Spacetrack prediction bulletin issued 9 hours before decay, is shown in Fig.1. This track was found to be consistent with the observations, and its estimated error over southern England is 5 km (s.d.). Marked on the track are times in hours and minutes U.T., and the probable height of the satellite, obtained by fitting to the observations various theoretical profiles of height

versus distance[3] and choosing the profile that fitted best. The estimated error in height is about 5 km (s.d.). Observations accurate enough to be used in determining the height or final burnout area were made from Bromley (D. Rees), Datchet (P.E. L. Neirinck), Margate (A. Fédou), Ottershaw (D. M. C. Walker), Sturry (D. Imhof) and Tonbridge (P. Daly). These sites are marked by squares on the map, and the azimuths of the useful observations are indicated by the broken lines. The sighting from St. Andrews was helpful in confirming that the satellite was self-luminous at latitude 56°N.

The striking appearance of the decaying satellite inspired a large number of sketches, often beautifully drawn in colour. Unfortunately only one unimpressive photograph is available[4] and the drawings differ so greatly among themselves, in both shape and hue, that it would be misleading to select any single one of them as representative. The differences between the drawings can be partly attributed to the changes in the appearance of the satellite in the course of its decay, and the different angles from which it was being observed. As it crossed the north of England, from Lancaster to Nottingham, the object had a bright head with a cylindrical tail several degrees long, outlined by bright lines at its edge. A few fragments were being thrown off from the head, appearing as 'balls of light' that gradually faded. As the incandescent rocket approached the London area, the bright head became larger, the greater numbers of fragments broke off, streaming behind the head and gradually falling away. These balls of light were thrown off upward as well as downward, were often as bright as Venus, magnitude -4, and extended over an arc of between 10° and 20°. At any particular time at least 10 of these subsidiary fragments were visible, and some witnesses reported as many as 100. As the object proceeded south of London, the break-up became more complete and observers described it as a 'formation of lights', and 'a group of more than 30 bright lights, each leaving an illuminated trail'. The colours of the head and the glowing fragments were reported as being mainly white or whitish yellow, but there are also reports of orange, red, blue and green fragments. The fragments in the final burnout area ceased to glow after they had dropped to a height of about 30 km.

Cosmos 253 was launched on 13 November 1968 into an orbit with an initial perigee height of 200 km, an initial apogee height of 333 km, and an inclination to the Equator of 65.4°. The satellite was recovered from orbit after five days. The final-stage rocket, the object that decayed over England, had a rather similar initial orbit and was presumably the usual

65° Cosmos rocket[5], about 6 metres long and 2 metres in diameter, with a mass of about 1500 kg. These rockets usually tumble at a rate of about 1 rev/sec and the visual appearance of the rocket during its decay was consistent with the assumption that it was still rotating, with pieces being thrown off above and below as it lost structural strength through heating.

Solid lumps of metal have quite often been picked up from the ground after the re-entry of previous large satellites; for example, one of the pieces of Sputnik 4 found near Lake Michigan[6] in September 1962 weighed 9.5 kg. The only report so far received of pieces from Cosmos 253 rocket being picked up is of one small fragment at Southend[4], and, as shown in Fig.1, most surviving fragments probably fell in the sea south-east of Dover, or perhaps in northern France. Objects have been re-entering the atmosphere from orbit at a rate of about one per day in the past year. Most of these pieces are small and burn up completely on re-entry, but about once a week a large object decays that might shower solid fragments into the lower atmosphere. This debris constitutes a small but not entirely negligible hazard to aircraft. and the Volunteer Flight Officer Network[2] already provides warnings to co-operating Airlines about the times and tracks of decaying satellites that are likely to cross their traffic routes.

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Fig.1

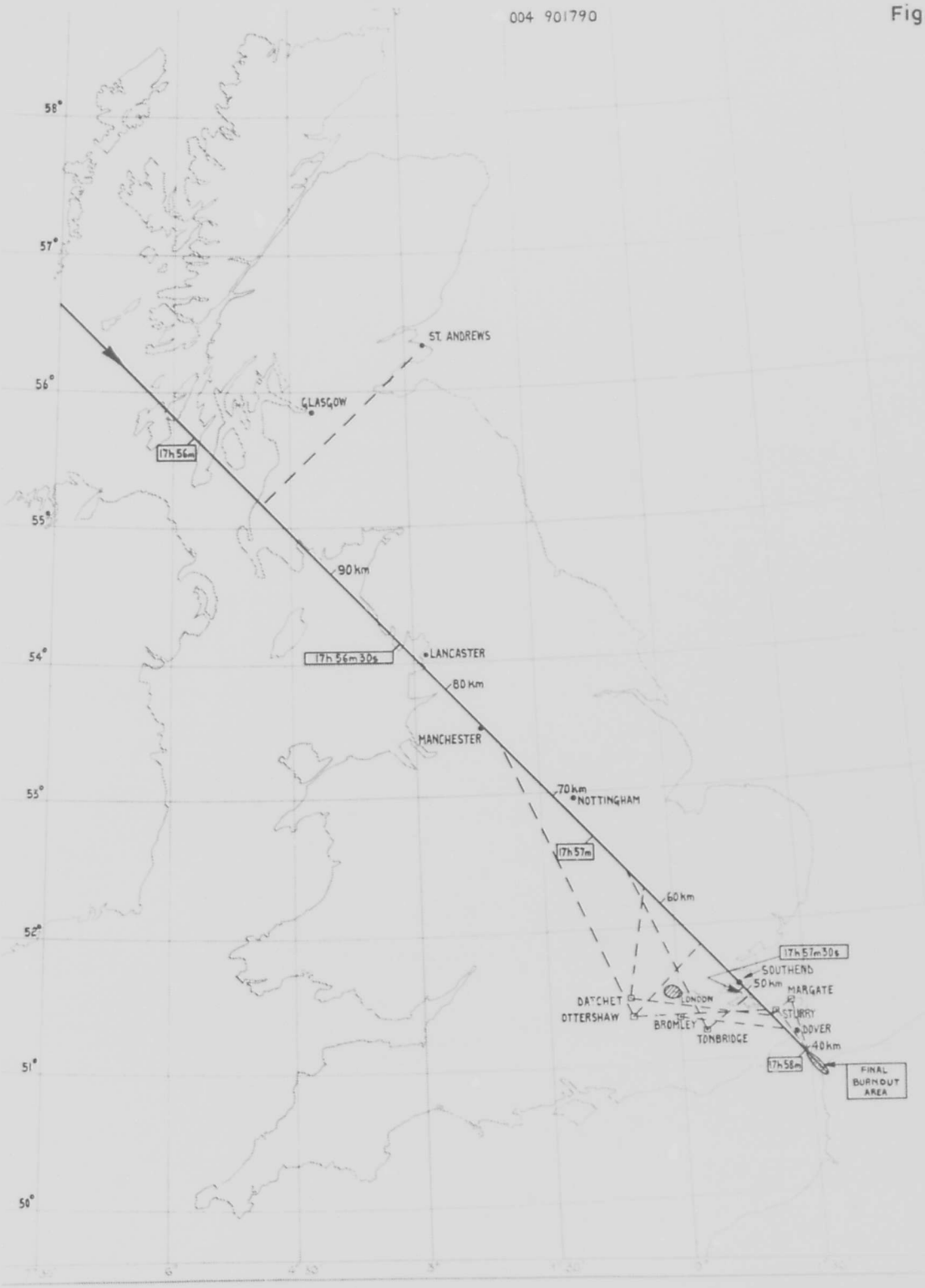

FIG.1 TRACK OF COSMOS 253 ROCKET DURING DECAY