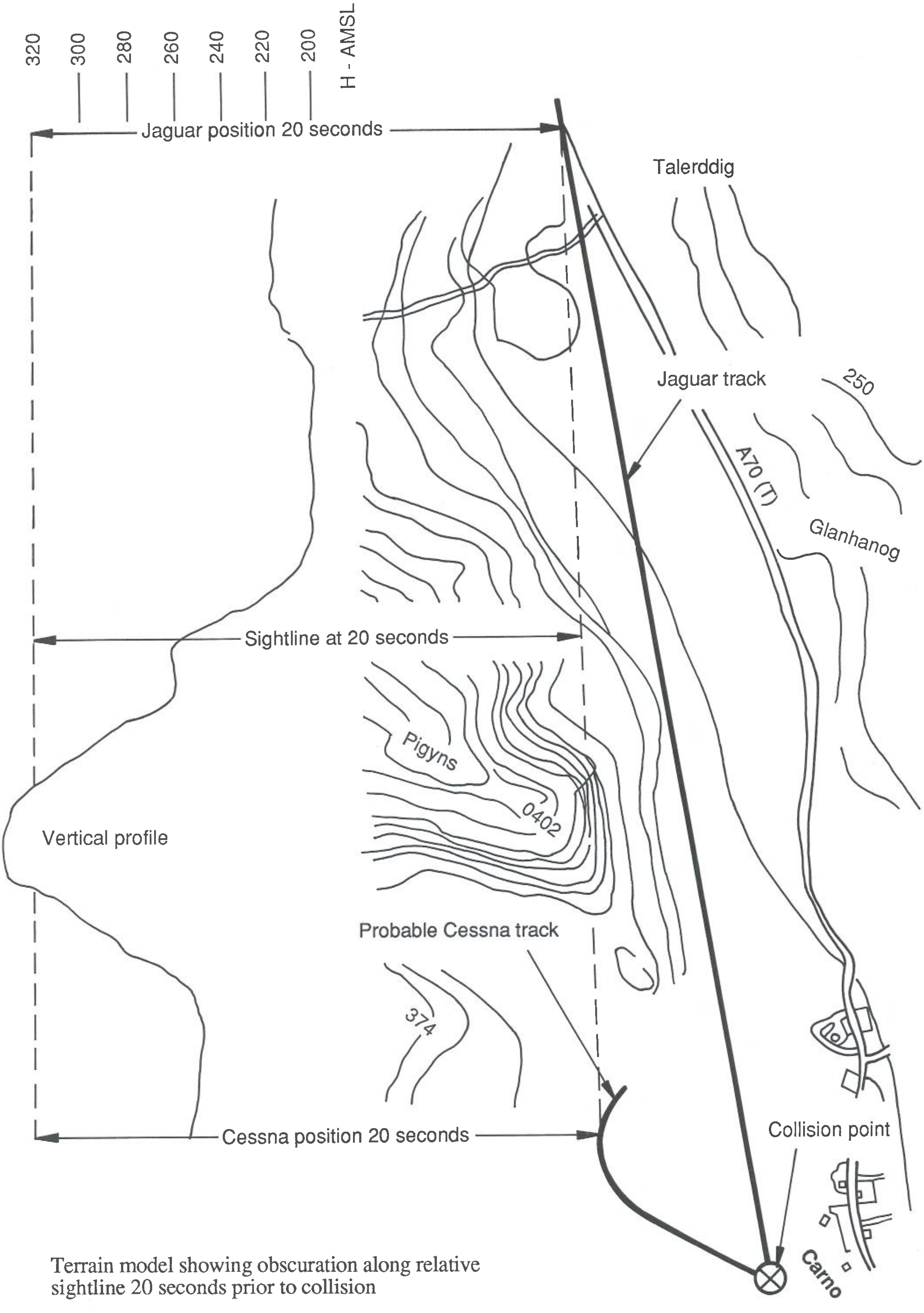
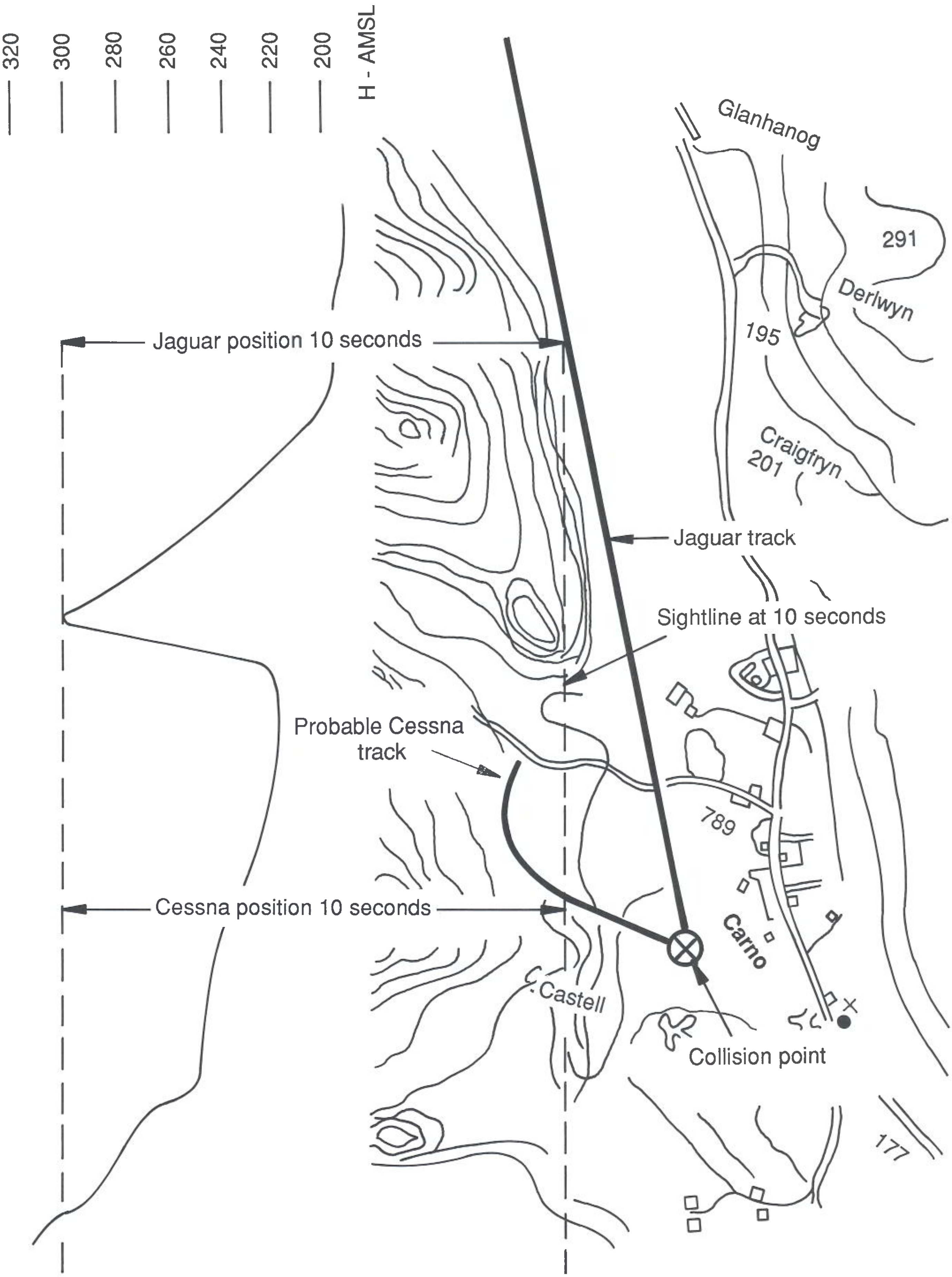
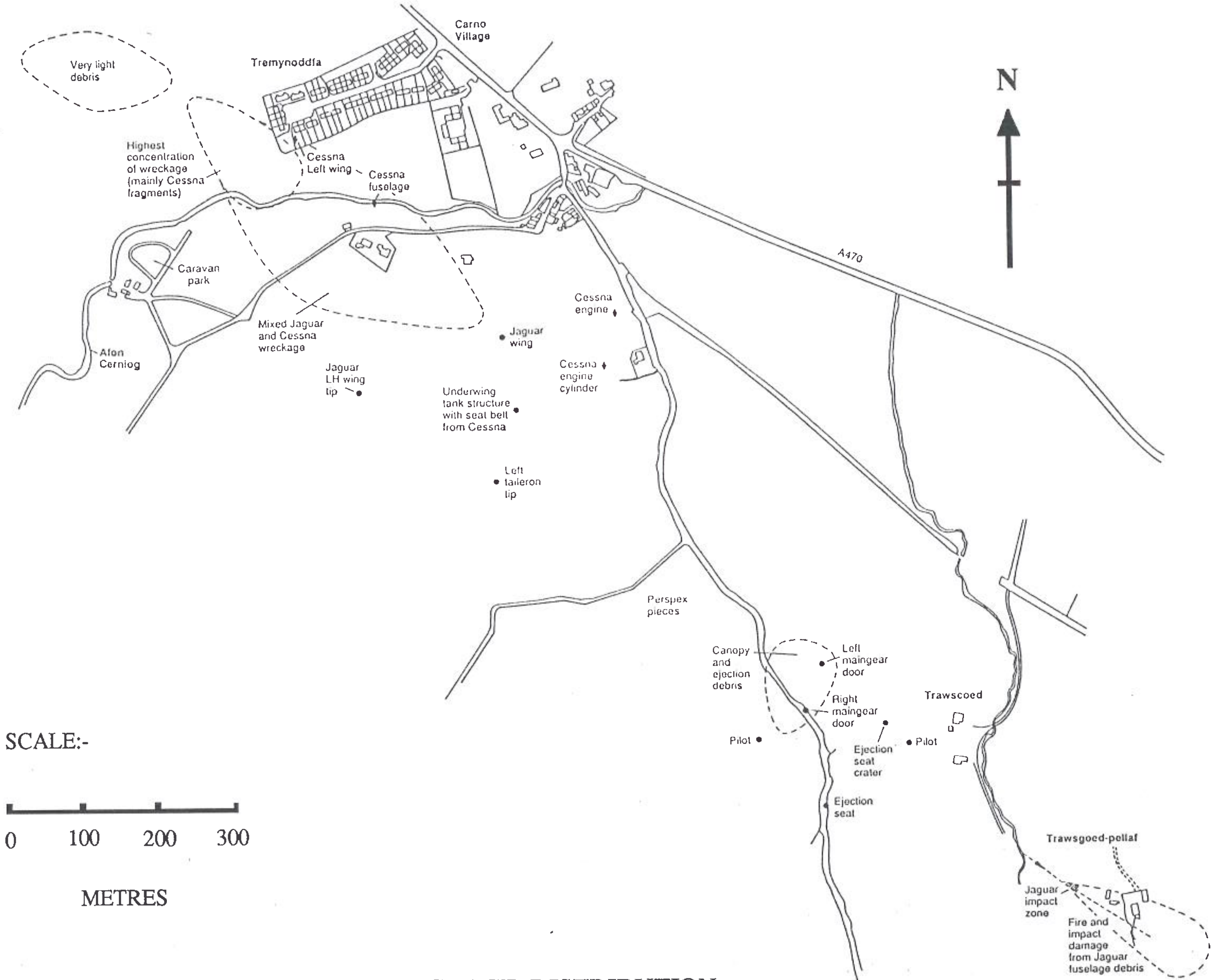


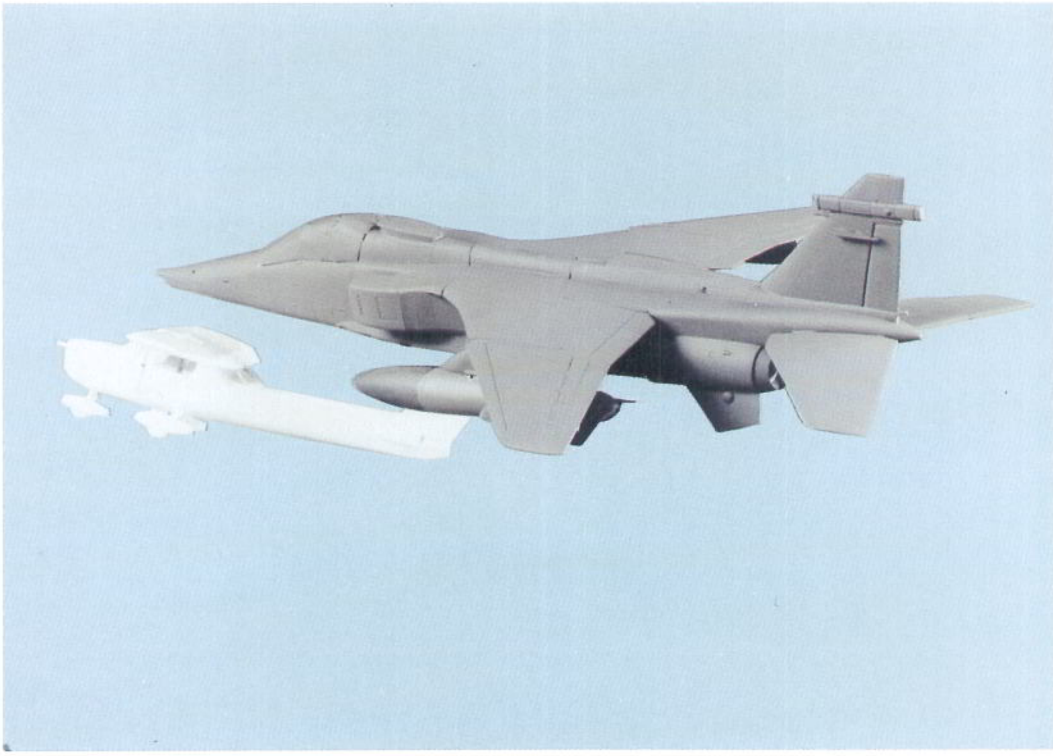
Terrain model showing obscuration along relative sightline 20 seconds prior to collision



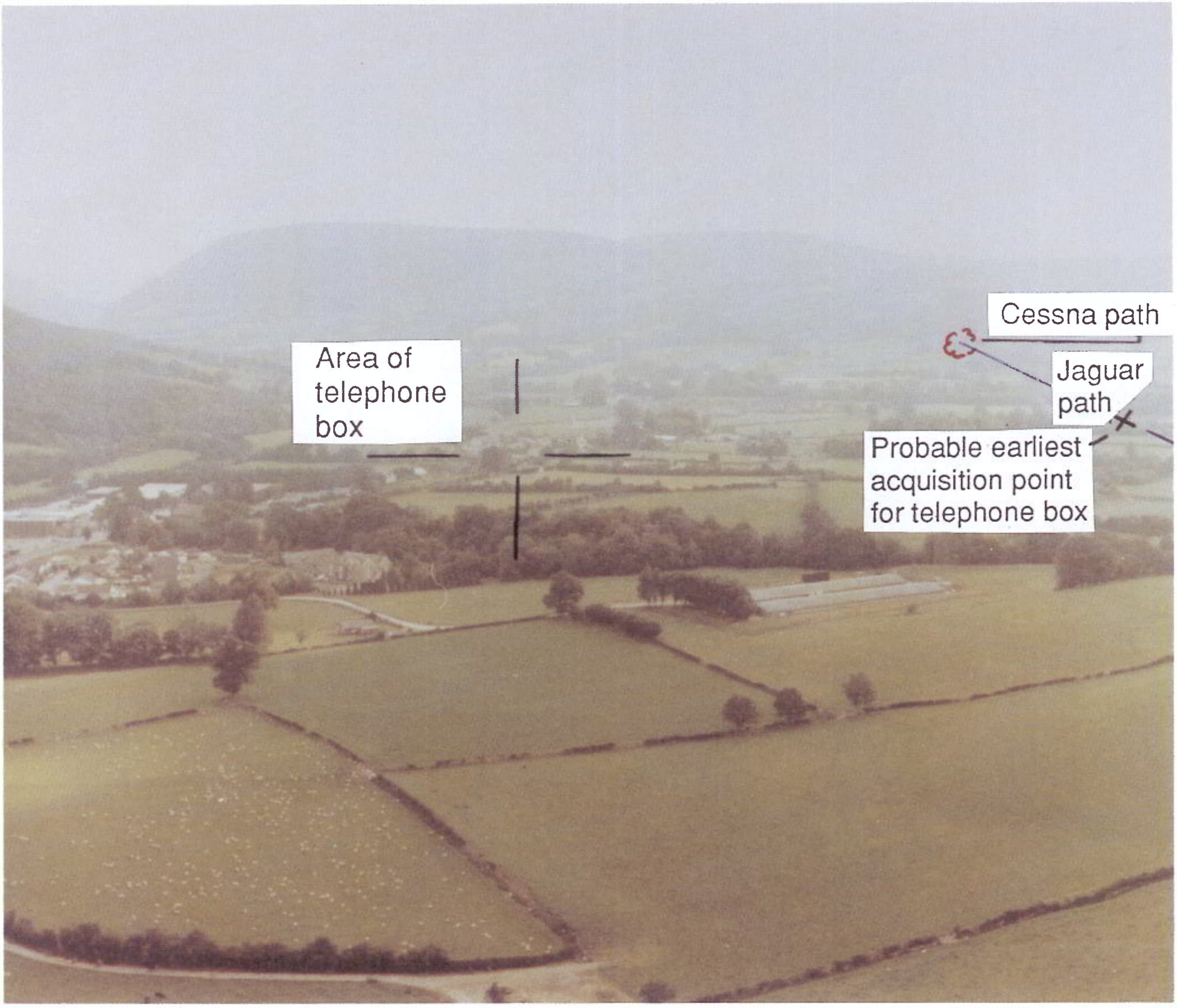
Terrain model showing probable unmask point 10 seconds prior to collision



WRECKAGE DISTRIBUTION



Collision Geometry
(Model represents single seat Jaguar)



View of Carno from a point equivalent to 8 seconds before collision

AIRCRAFT CONSPICUITY AND VISUAL DETECTION

[A summary of discussions held with the Principal Psychologist, Psychology Division, Institute of Aviation Medicine.]

1 Introduction

The following consideration is given to the question of conspicuity of each aircraft as viewed from the other. The technique used to assess conspicuity is described in RAF IAM Report 702[1] as a general technique applied in hypothetical conditions. The assessment of conspicuity in a real event is more demanding and poses some significant difficulties. The results presented here are therefore somewhat speculative and represent only a best guess at the real situation. The primary difficulty involves the post hoc assessment of luminances and contrasts without any relevant measures taken on the day. Attachment A to this Appendix deals with the procedure adopted in this case.

2 The view from the Jaguar

Both aircraft were roughly level with the 300 metre (984 feet) contour. The line of sight from the Jaguar to the Cessna would intercept the 300 metre (984 feet) contour on the hills to the south at between 1.05 and 1.5 km beyond the Cessna. The Cessna, therefore, presented a small, positive contrast against the hill behind. The best estimate is that there was about a 1 in 10 chance that the Jaguar crew would have seen the Cessna before C -10 (ten seconds before the collision), had the ridge not been present. By C -5, the residual effect of terrain masking was very small and the probability that at least one of the Jaguar pilots would have seen the Cessna had risen to about 0.6, which means that there was about a 4 in 10 chance that the Cessna would remain undetected at until this stage.

Five seconds is a reasonable time in which to detect another aircraft, orientate towards it, analyse the conflict and take effective avoiding action. With only, say three seconds remaining, an unconsidered 'last ditch' manoeuvre by the handling pilot might still be effective. Between C -5 and C -3 the probability of detection would have risen significantly. This fact, and the fact that the surviving (non handling, rear seat) pilot has no recollection at all of seeing the Cessna, suggests that the attention of one or both pilots in the Jaguar may well have been directed away from the Cessna during the critical last five seconds. The rear seat pilot remembers discussing with the front seat pilot a telephone box to the east of their track at some stage shortly before the collision. This would be an adequate explanation of their failure to detect the Cessna during the last five seconds. In addition both pilots' attention would probably have been directed to the left, down the valley into which they were about to turn.

The visual search assumptions used in calculating the probabilities presented above take no account of obstructions in the field of view. The Cessna would have been about 10° right of

1 RAF IAM Report 702. Random mid-air collisions in the low flying system. J W Chappelow and A J Belyavin. RAF Institute of Aviation Medicine, Farnborough 1991.

centreline for the Jaguar pilots. This would put it behind the right hand windscreen / HUD support strut. The absolute effect of this obscuration can only be imagined. It would certainly impose a significant reduction on search efficiency. Even a pilot who searched with reasonable diligence behind all canopy obstructions would have only a small opportunity to detect the hidden conflict in the ten seconds between the end of terrain masking and the collision.

It is conceivable that the Cessna aircraft could have been fixated by one or both Jaguar pilots, but, being a small, mostly white object, remained undetected among white houses on the hillside behind. The Cessna would have been stationary in the field of view. The background, however, would have been moving at, on average, about 40 or 50 minutes of arc per second. This is well above threshold for the detection of relative motion and relative motion is an effective depth cue. It is, therefore, unlikely that confusion with other objects played a significant part in reducing the detectability of the Cessna.

3 The view from the Cessna

The Jaguar would have appeared against a forested hill background from the Cessna pilot's point of view. Because the hill was over six kms away it offered a relatively bright background and the Jaguar presented a negative contrast. The possible effect of the Jaguar's HISLs have been ignored since these are likely to have been of only minor benefit. Because the Jaguar was in roughly the eight o'clock position visual search in this case has been assumed to cover 360° in azimuth and +/-10° in elevation. This assumption is not merely a convenience. The risk of collision for a slow aircraft is more generally distributed in azimuth than for a fast aircraft. It is unlikely, however, that this point is widely appreciated among general aviation pilots.

Again, terrain masking initially had only a small effect on the outcome. On the assumptions given, the Cessna pilot had only about a 1 in 3 chance of detecting the Jaguar before C -5. However, this assessment must be regarded as largely academic. To determine the position of the Jaguar would require considerable head and body movement for detection, particularly as a substantial strut obscures that part of the visual field in the Cessna 152. In addition, it is quite likely that the Cessna pilot's attention was directed towards the village for at least some of the last ten seconds as he was engaged in photographic operations.

4 Conclusions

The effect of terrain masking was to eliminate a small chance of detecting the collision before C -10. Assuming continuous, unrestricted search, the probability of detecting the conflict with at least five seconds left to manoeuvre was about 0.6 for the Jaguar crew and 0.35 for the Cessna pilot. However, continuous unrestricted search is a demanding assumption and unlikely to be realised in practice. The position of the Jaguar behind a strut at 8 o'clock makes it very unlikely that the Cessna pilot would have scanned the appropriate area. Similarly, the location of the Cessna behind forward window / HUD struts in the Jaguar would have significantly reduced the probability of detection. It seems quite probable that the Jaguar crew were attending to ground features to the left of track during the last five seconds before collision.

Assessment of Contrast

The assessment of conspicuity requires measures of contrast, apparent size, and meteorological visibility. With no direct measures of contrast available, it was necessary to estimate the likely contrasts from measures of reflectance.

Apparent size: 'Wire frame' computer models of the Cessna and Jaguar were constructed and used to estimate the effective visual area of each aircraft as viewed from the other. At 63° to the line of sight, the Cessna's effective area was 5.2 square metres, of which 2.19 square metres was assigned to its horizontal red stripe.

Aircraft reflectance: The reflectance of the Cessna 152 was measured in a hangar at RAF Abingdon. Measurements were also made of the size of fuselage and wing markings. The average reflectance for white areas was 0.84, and that for red areas was 0.25. A mean reflectance of 0.59 was assumed, taking into account the apparent relative proportions of each area at 63° to the line of sight. Averaging was adopted as a reasonable approximation as the aircraft would have subtended only a few minutes of arc at the Jaguar pilots' eyes throughout most of the critical period.

RAE Technical report 80080[2] gives values for the contrast of matt dark sea green and matt dark grey camouflage against the horizon sky. Taking an average value of -0.74 for contrast (Co) and 0.25 for ground reflectance (R'), a value of 0.25 for aircraft reflectance (R) was obtained using equation 1 (from Vision through the atmosphere by W E Knowles Middleton - University of Toronto Press, 1952)).

$$R = \frac{(Co+l)}{(0.5*(1+R')+0.667*(R'+2/pi))} \qquad (1)$$

Using the calculated values for reflectance, the intrinsic luminance of each aircraft (Lo) was estimated using equation 2 on an assumption of 3000cd/square metres for horizon sky luminance (Ls).

$$Lo = R*Ls*(0.5*(1+R')+0.667*(R'+2/pi)) \qquad (2)$$

For the Cessna this value was 2162cd/square metres, and for the Jaguar, 780cd/square metres.

Background luminances: From positions on the ground close to the Jaguar's position at C -5, measurements were made, in 30 km visibility, of the horizon sky luminance, and terrain luminance just below the sky line. This was done at the same time of day (+/-30 min) as the

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2 RAE technical Report 80080. A further evaluation of paint schemes for the camouflage of aircraft against ground to air optical detection. P J Barley. Royal Aircraft Establishment, Farnborough, 1980.

accident took place. Looking south, in the direction of the Cessna's track, the view was of grass covered hillside. To the north, in the direction from which the Jaguar came, the background was wooded hillside.

Reference to a large scale map put the southward skyline at about 3 km. The average apparent luminance (La) of the hillside just below the skyline was 238cd/square metres. The average horizon sky luminance (Ls) was 529cd/square metres. The intrinsic luminance of the hillside was calculated using equation 3.

$$Lo = (La/exp(-3*R/V)) + Ls*(1-1/exp(-3*R/V)) \qquad (3)$$

where R is the range, and V is the visibility.

The reflectance follows directly from the intrinsic luminance, and was found to be 0.25. This is about twice the recognised value for long or thick grass, but compares well with other measures taken of close cropped or sparsely covered fields. Assuming an horizon sky luminance of 3000cd/square metres on the day of the accident, the intrinsic luminance of the hillside was estimated as 763cd/square metres. The visibility on the day was about 10 km. Hence the apparent luminance of this hillside as seen from the Cessna was, from equation 4, 1486cd/square metres.

$$La = Lo*e(-3*R/V) + LS*(1-exp(-3*R/\sim) \qquad (4)$$

This could be regarded as a virtual background against which the Cessna formed a positive contrast, 0.46.

$$Co = (Lo(Cessna) - La(hillside))/La(hillside) \qquad (5)$$

With this value, the procedure described in RAF IAM Report 702 could be followed to estimate the probability of detection.

The Jaguar's background: The view to the north did not yield so easily to this approach, possibly because, when the measurements were taken, it was partially directly illuminated with some cloud shadows. This is not serious, however. Reference C gives a value of 0.04 for the reflectance of woods, and at the relatively long range (about 6.25 km) from which the Cessna pilot would have had to view the Jaguar's background, the apparent luminance of the background would be largely determined by light scattered from the sky. The luminance of this background viewed from the Jaguar was calculated, on this basis, to have averaged 2297cd/square metres. This could be regarded as a virtual background against which the Jaguar would have had an intrinsic contrast of -0.66 (equation 5).

FIGURE 1: PROBABILITY OF DETECTING THE CESSNA

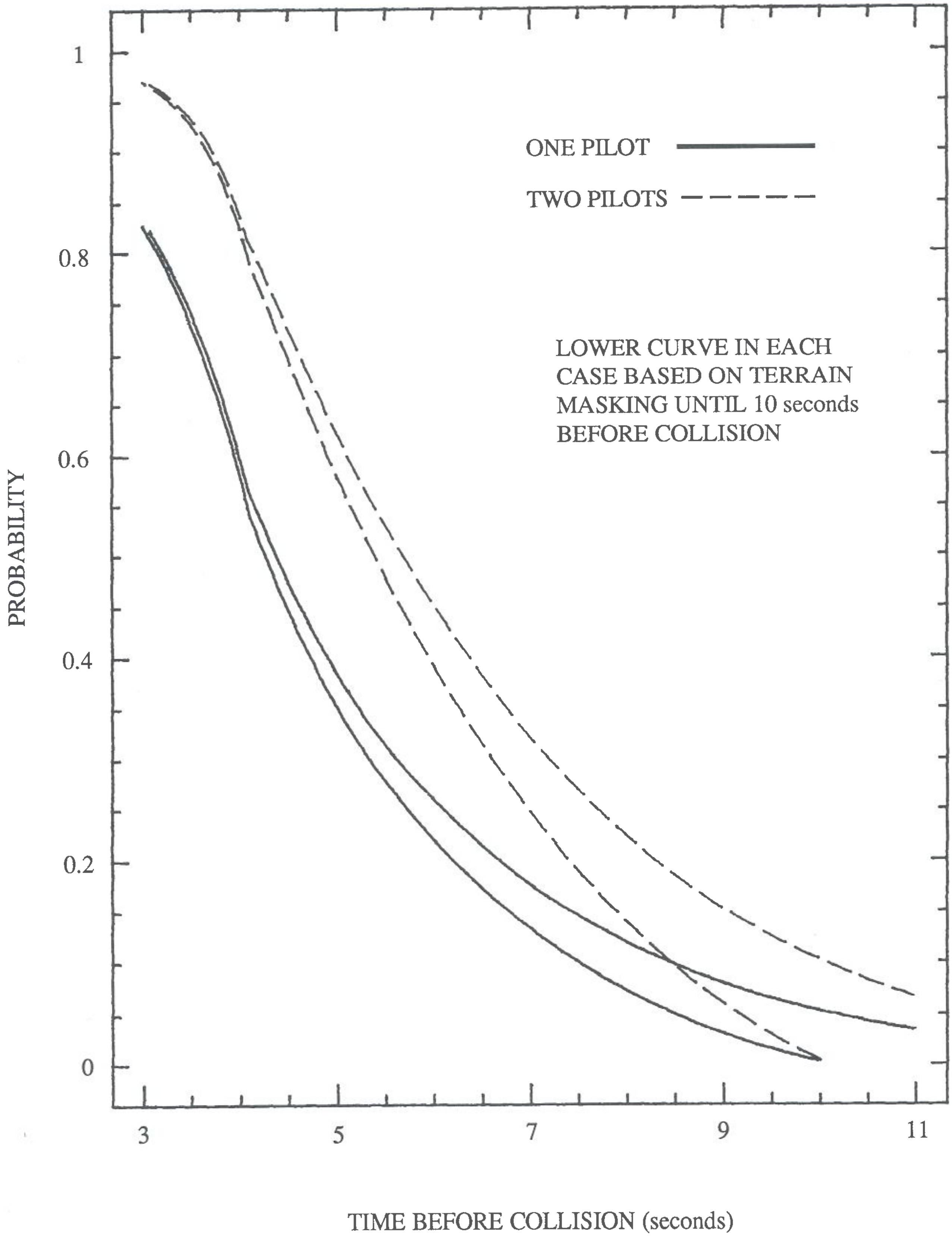
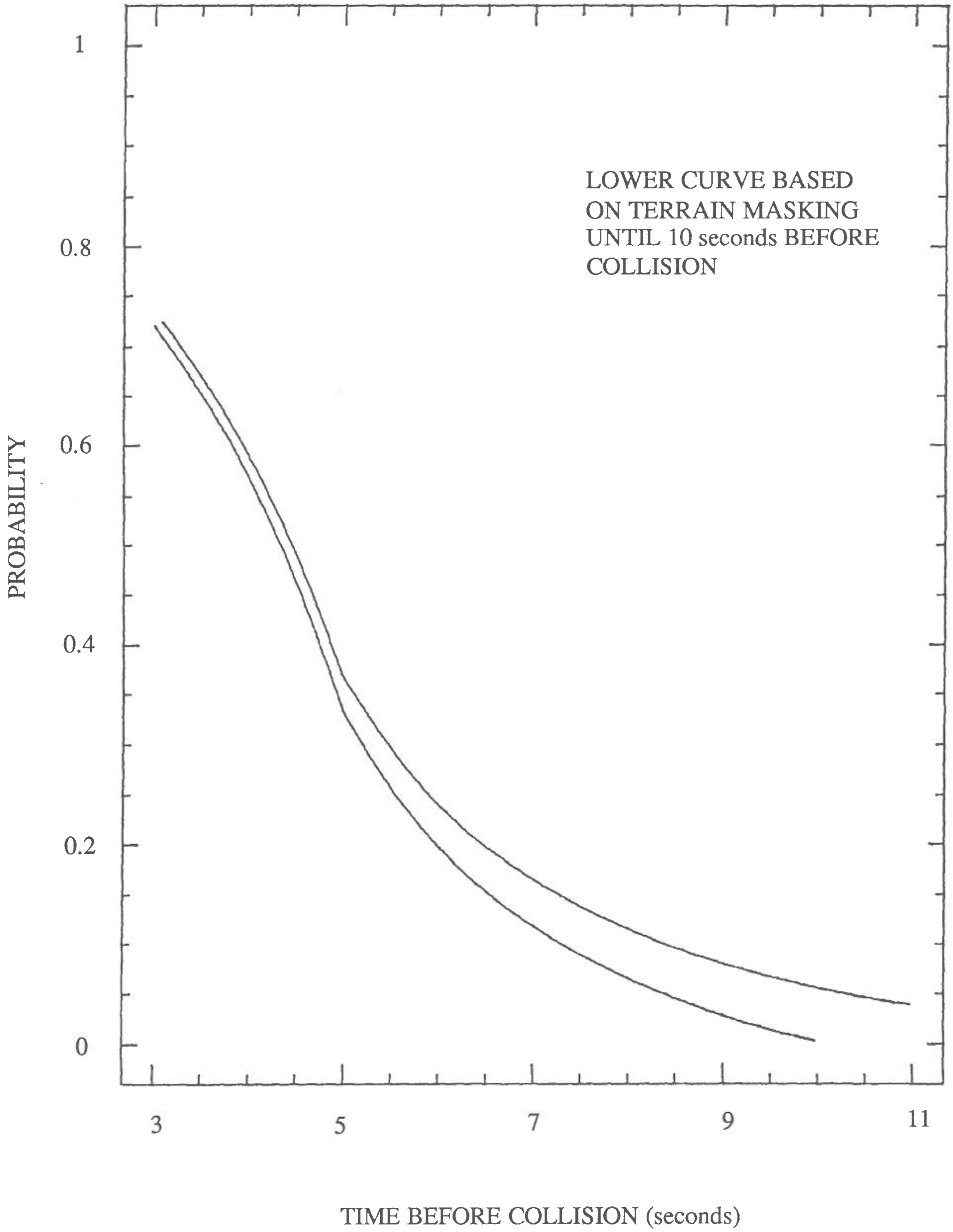


FIGURE 2: PROBABILITY OF DETECTING THE JAGUAR



LOW LEVEL CIVIL AIRCRAFT NOTIFICATION PROCEDURE (CANP)

1 Introduction

1.1 Some military and civil aircraft are required to operate at very low heights; the former for essential training and the latter to carry out authorized aerial work. These flights take place in the Flight Information Regions outside Controlled Airspace where collision avoidance must necessarily be based on the 'see and avoid' principle, assisted as far as is possible by information on known traffic. It is not practicable, in meaningful ATS terms, to establish and subsequently employ traffic information on all civil aircraft operating below say, 2000 ft agl. Neither is it possible to disseminate details of military low level flights to civil operators with sufficient speed, or in such a manner, so that civil pilots can use this information as the sole means to avoid military aircraft. Nevertheless, the greatest conflict of interest occurs at or below 500 ft agl where the majority of low level military and civil operations take place. Therefore, a system has been devised to collect information on civil aircraft engaged in aerial work such as crop spraying, photography and surveys within this height band, *ie* at or below 500 ft agl and to distribute it to military operators to assist in planned avoidance. This system is known as the Low Level Civil Aircraft Notification Procedure (CANP).

1.2 Before commencing any low flying sortie, military pilots receive a comprehensive brief on all factors likely to affect their flight and this brief includes details of relevant CANP reports. Hence, maximum participation in CANP by civil pilots engaged in aerial work at or below 500 ft agl is essential if full benefit is to be obtained from the procedure.

2 Procedure

2.1 The London Air Traffic Control Centre (Military) Tactical Booking Centre (TBC) (Telephone Number 0895 - 426701) is the central authority for co-ordinating information relating to military low flying, including CANP. A FREEPHONE to TBC is provided (FREEFONE 2230) to assist civil operators to participate in CANP, and pilots intending to fly on authorized low level work or their representatives are encouraged to use this facility whenever possible.

2.2 CANP telephone messages should be prefixed 'CIVIL LOW FLYING' followed by details of the intended flight in the following format:

(i) Type of activity;

(ii) Locations(s): preferably as a 6 figure grid reference taken from an OS 1:50 000 map, although latitude and longitude will be accepted. The name of a nearby village or town is also required;

(iii) Area of Operation(s): as a circle with a specified radius centred on the location(s) whenever possible;

(iv) Date and Time of intended operation(s): start and finish in local time;

(v) Operating Height(s): lower and upper limits agl;

(vi) Type(s) of aircraft;

(vii) Contact Telephone Number;

(viii) Operating Company and Telephone Number.

Example:

'CIVIL LOW FLYING'
CROP SPRAYING
SF 178 259 - NEAR LUPITT
1 nm RADIUS
12 SEPTEMBER - 1500 to 1700
GL to 200 FT AGL
PAWNEE
LUPITT 0765 - 2497
REDSTONE AVIATION - EXETER 0392 - 51423

3 Pre-Notification Requirement

3.1 Pre-notification of intended operations should be communicated to TBC not less than 5 hours and not more than 24 hours before commencement. In order to relate notifications as close as possible to the actual operations, pre-notification of operations due to take place up to 1300 Winter, 1200 Summer should be made the previous day and those due to take place after 1300 Winter, 1200 Summer should be pre-notified on the morning of the same day. It is accepted that there will be occasions when the minimum pre-notification time cannot be provided. Nevertheless, late notifications should still be made and every effort will be made to distribute the information as widely as possible although reports, received less than 5 hours before an operation is due to commence, are progressively less likely to reach all military pilots before they depart on their low level sorties.

4 Operating Area Boundaries

4.1 Military pilots will aim to provide adequate avoidance of either the area or activity reported under CANP, depending on the circumstances. Therefore, the lateral and vertical boundaries given to define the area of activity should equate only to the parameters within which the work will be carried out and should not build-in an allowance as a safety factor. Normally, it is expected that agricultural aviation operations will be contained within 1.5 nm radius circle and the vertical extent of the airspace involved will not exceed 200 ft agl.

5 Cancellation

5.1 Activities reported under CANP considerably restrict the airspace available for military low flying training. Thus, in order to maintain the integrity of, and confidence in, the CANP system, every reasonable attempt should be made to inform TBC immediately it is obvious that an activity previously reported will no longer take place, irrespective of the time remaining.

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