PART 1.4
FINDINGS

PART 1.4 – FINDINGS

Factors considered by the panel

1. The Panel considered that the following factors may have had a bearing on the accident:

a. Local airspace.

b. Orders and Instructions.

c. Supervision.

d. Authorisation of flights.

e. Briefing of flights.

f. Aircraft systems integrity.

g. Tutor conspicuity.

h. Meteorological factors.

i. Aircraft handling.

j. Pilot incapacitation.

k. Survivability.

Human Factors

2. The Panel concluded that Human Factors had a substantial bearing upon the accident. Therefore, as well as addressing Human Factors within each of the sub-paragraphs above, findings relating to Human Factors are also addressed as a discreet section, with a grouping and order of factors that reflects the advice of the RAFCAM Aviation Psychologist:

a. Aircraft separation.

i. Deconfliction.

ii. Situational Awareness.

b. The 'See and Avoid' principle.

c. Human Factors affecting the ability to 'See'.

i. 'Cannot See'.

(1) Lookout.

(2) Arousal levels.

(3) Limitations of the Human Visual System.

(4) Aircraft conspicuity.

ii. 'Will Not See'.

(1) Obscuration.

(2) Cockpit workload and in-cockpit distraction.

(3) Expectation.

d. Human Factors affecting the ability to 'Avoid'.

i. Response time.

ii. Threat recognition.

iii. Collision avoidance manoeuvre.

e. Studies to assess the effectiveness of 'See and Avoid'.

f. Improving the safety of VFR operations.

i. Collision probability.

ii. See and Avoid limitations.

iii. Enhancing deconfliction.

iv. Alerted search.

v. Electronic conspicuity.

g. Lookout techniques.

i. Current RAF lookout scan pattern.

ii. The aim of lookout.

iii. Most likely threats.

iv. Most likely Angle of Arrival.

v. Pilot experience.

h. Summary of Human Factors conclusions.

Analysis of factors

Local airspace

3. MOD St Athan airfield is located within a complex of Class D airspace[1] surrounding Cardiff Airport which extends from the surface to FL 105 as far as Nash Point to the west. Once past Nash Point, the base of controlled airspace is 2000 ft until Ogmore-by-Sea, with Class G airspace extending from Ogmore-by-Sea to the west. There is no usable Class G airspace within practical range to the east of MOD St Athan and the Panel noted that the majority of UWAS flying activity is conducted in the area to the west. The useable local flying area extends 20 nm west of St Athan and is bounded in the south by the coastline[2] and by the southern edge of Airway G1 in the north. High ground inland means that additional altitude must be gained if aerobatics are to be performed while manoeuvring in the overhead of the towns of Bridgend and Cowbridge is avoided. When the time available for AEF flights (typically 25 mins per cadet) and the transit distance to the local flying area (15 nm) is factored the areas most suitable for general manoeuvring and aerobatic flight become very limited; this time limitation is mitigated in part by the relatively few movements from MOD St Athan as compared to other AEF and UAS locations. The Panel concluded that the limitations on suitable operating airspace, including the time available for an AEF sortie in relation to the distance of the local flying area from MOD St Athan, were all contributory factors in the accident.

Orders and instructions

4. **Air Navigation Order: Rights of Way**. Both accident pilots were under remit to operate their aircraft in accordance with the Air Navigation Order[3] and TGO(E)s, applying the most restrictive regulatory condition of both documents. In either case, whilst flying under Visual Flight Rules (VFR) in Class G airspace, there is no requirement to use a radar service unless the Aircraft Commander considers it necessary. The 'Rules of the Air'[4] stipulate under which circumstances an aircraft has the right of way and what manoeuvre is expected of conflicting traffic in order to maintain safe separation. When 2 aircraft are converging, the aircraft on the right has right of way and should maintain course and speed. Nevertheless, as it cannot be assumed that the pilot who should give way has seen the other aircraft, all pilots are ultimately responsible for maintaining safe separation, irrespective of the rights of way[5]. As G-BYUT and G-BYVN converged on 11 Feb 09, G-BYVN was to the right of G-BYUT, which affords right of way to G-BYVN. However, the panel were unable to determine whether either pilot saw the other aircraft at all or in sufficient time to execute an avoidance manoeuvre.

Annex I

Annex I

5. **MOD St Athan local procedures.** Revised UWAS departure and arrival procedures had been introduced on 5 Jan 09 in order to improve efficiency and facilitate better coordination with Cardiff ATC. Two departure procedures were available to the pilots of G-BYUT and G-BYVN. Both aircraft

Annex H,O

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[1] Airspace is classified A-G depending upon the regulations to be applied for flights within their specified dimensions. Flights in Class D airspace may be IFR or VFR and all flights are provided with an ATC service.
[2] Cadet flying restrictions TGO(E) (TE365.101.2b (1)) prohibit AEF cadet flights over the sea, outside gliding range of land.
[3] CAP 393 Air Navigation: The Order and the Regulations, 30 Mar 2007.
[4] Formally termed 'General Flight Rules' in CAP 393.
[5] 'it shall remain the duty of the commander of an aircraft to take all possible measures to ensure that his aircraft does not collide with any other aircraft.' CAP 393, Section 2, Page 7, Para 8 (1).

commanders requested and were cleared for a low VFR departure, climbing to not above 1500 ft QFE and following the coast to Nash Point and onwards to Ogmore-by-Sea, which delineates the edge of the Cardiff CTA. Thereafter, aircraft are free to climb, remaining clear of controlled airspace, and may remain on St Athan tower frequency unless a radar service is required from Cardiff Approach. In good VFR conditions, it is normal practice to operate without the potential distraction imposed by a busy radio channel and neither accident aircraft made radio calls to Cardiff Approach (VHF). The Panel noted that the implementation of the new VFR departure and arrival procedures had not been incorporated into the MOD St Athan Flying Order Book (FOB) by the airfield manager as of the 11 Feb 09 but this had no bearing on the accident as both pilots had been briefed and were familiar with the new procedures. The Panel concluded that all orders and instructions were adhered to. However, the Panel noted that the new Low VFR departure procedure allowed both pilots to remain on the St Athan tower frequency during departure and in the local flying area unless they chose to contact Cardiff Approach for a service. The Panel found no evidence that either pilot was in contact or listening to Cardiff approach during flight. Although a UHF discrete frequency is available there is no evidence to suggest that either aircraft made contact with each other. The Panel concluded that the decision by both pilots to remain on the St Athan tower frequency while flying in the local flying area, in accordance with local procedures, meant that they would not have received traffic information and that this was a possible contributory factor in the accident. Annex D

6. **AEA Fitting**. Both cadets were fitted with EB85/2 parachutes and Mk 25 LSJs. TGO(E)s specify that LSJs are not to be worn over the EB85/2 parachute but the Panel identified that the fitting procedures used by the VTAe SE staff details that an LSJ can be worn over an EB85/2 parachute providing the adjustable harness is in the 'Large' configuration but not in the 'Medium' or 'Small' configurations. In G-BYUT the cadet's parachute was set at 'Large' but the parachute worn by the cadet in G-BYVN was too badly damaged by fire to assess and the Panel noted that there was no record of the configuration of the cadets' parachutes. The cadet passenger manifest, which is normally annotated to indicate which cadets are not fitted with an LSJ, was not presented to the Panel; it was reported as having been present when all documentation was initially impounded but appears to have been misplaced subsequently. Despite subsequent searches at UWAS and RAFCAM the manifest has not been identified. Despite the discrepancy in procedures, the Panel did not consider AEA fitment to be a factor in the accident. Annex L

Supervision

7. Both accident flights were supervised by OC UWAS in accordance with TGO(E) 305 and the MOD St Athan FOB. The Panel examined all aspects of this supervision and concluded that OC UWAS had exercised thorough and effective supervision of both flights in accordance with his responsibilities as specified within TGO(E)s. The Panel concluded that supervision was exercised to the standard expected and was not a factor in the accident. Witness 1 Annex I

a. **Flying discipline**. The air cadets were cousins and the Panel considered the possibility that this might have prompted either pilot to reduce separation between G-BYUT and G-BYVN for the purpose of observing the other aircraft. The Panel noted however that neither air cadet had mentioned that they were related during their SE kitting procedure and therefore considered that it was unlikely they would mention it to the pilot subsequently, being more likely to be absorbed by the experience of their first flights. Nevertheless, the Panel could not Witness 5 discount this possibility and therefore considered that either or both pilots of G-BYUT and G-BYVN were attempting to effect an intercept, join-up or otherwise deliberately fly in proximity so that the cadets could see the other aircraft and its occupants. Neither pilot had a history of flying indiscipline and the Panel encountered no evidence of impromptu intercepts that might reveal a pattern of such behaviour. Interviews with unit colleagues revealed that both pilots were highly regarded as disciplined and professional aviators. Furthermore, the flight profiles recorded, especially the lack of a height split, do not match either an intercept or join-up profile. A deliberate endeavour to join could have been coordinated on the quiet frequency and a height split established, whereas an unannounced intercept would most likely preserve both a height advantage and nose-tail separation and not turn belly-up to a prospective target. The Panel did not consider flying discipline to be a factor in the accident. Annex C Witness 1,2,3 Annex E

b **Deliberate act**. On the strength of formal interviews with Service colleagues and SW Police statements from family members, the Panel also discounted the prospect of the collision arising from a deliberate act. The Panel did not consider deliberate acts by either pilot to be factors in the accident. Witness 1,2,3 S90B, S101, S102

Authorisation of flights

8. The flights by G-BYUT and G-BYVN were correctly authorised by OC UWAS as air experience flights in accordance with TGO(E) 301; both pilots initialled the authorisation sheets as captain. The Panel did not consider authorisation of flights to be a factor in the accident. Witness 1 Annex I

Briefing of flights

9. Both pilots of G-BYUT and G-BYVN completed a standard outbrief in the Sqn operations room prior to flight. The Panel did not consider the briefing of the flights to be a factor in the accident. Witness 1

Aircraft systems integrity

10. Both aircraft were reported as serviceable by the pilots who flew the aircraft immediately prior to the accident sorties. By the time the Panel arrived at the crash site, the wreckage of both aircraft had been disturbed to allow for the recovery of the pilots and cadets as well as to allow the commencement of site remediation. However, AAIB personnel did examine the aircraft prior to movement and a plot of the wreckage was completed by JARTS. Additionally, the Panel was provided with a significant amount of photographic and video evidence of the aircraft in situ at the crash site, some of which were taken only minutes after the ground impact. The wreckage of both aircraft, inclusive of the wreckage trail, was recovered and transported by JARTS to a hangar at MOD St Athan for further detailed examination. The wreckage was laid out and technically examined by the AAIB personnel and the Engineer member of the SIP. Certain components were functionally tested and found to be serviceable post crash. The examination and testing did not identify any areas of concern with the systems and components of either aircraft. The aircraft maintenance documentation and technical records were reviewed by the SI Engineer member and the AAIB inspector. No issues of significance were identified with the maintenance documentation and technical records of either aircraft. A full description of the wreckage examination is at Annex K. The Panel is satisfied Witness 1,12 Annex F Annex Q Annex K Annex S Annex K

that aircraft systems integrity and maintenance were not factors in the accident.

Tutor conspicuity

11. The Panel considered the effect of Tutor conspicuity within the analysis of Human Factors but initially noted pertinent technical characteristics.

a. **High Intensity Strobe Lights (HISLs)**. The Tutor is equipped with HISLs with an effective intensity of 2000 candelas. Having determined that both G-BYUT and G-BYVN left the pan with their strobes operating normally, and that the right wing tip strobe of G-BYUT was serviceable when tested post collision, the Panel considered that both aircraft were likely to have had their strobes on and operating normally (white) at the time of the accident. Annex S Witness 7,8

b. **Colour scheme**. The colour scheme for the Tutor was considered when it was brought into service in 1997. The advice at the time, based upon a previous FJ study, was that an all-over black colour scheme provided for increased conspicuity, particularly for fast moving aircraft. Although a view persisted that this had reduced applicability to slow moving aircraft, a predominantly black paint scheme was nevertheless assessed on a single Bulldog and the Firefly adopted a black and yellow scheme. The Bulldog Replacement Programme sought advice from the contract bidders and aircraft manufacturer on the feasibility of a black colour scheme for the Tutor and the likely associated costs. The aircraft manufacturer (Grob) stated that an all black paint scheme would require Airworthiness regulatory approval and an extensive thermal analysis programme incurring additional costs. Following several months of discussion a decision was taken to proceed with an all white scheme but the final white colour scheme included blue reflective flashes on the fuselage sides. In-service experience confirmed that the Tutor aircraft was difficult to see in certain circumstances and this led to further analysis of Tutor conspicuity in 2001 which concluded that the white colour scheme made the Tutor easy to see in certain light conditions but against a bright background there was little contrast. Annex AG Annex AG

c. **Electronic conspicuity**. The last review of Tutor conspicuity was in 2004 in response to a request from the then Command Flight Safety Officer (CFSO) to conduct a risk assessment. No 1 EFTS staff concluded that the overall risk category was B (undesirable risk) and that the Tutor was difficult to acquire in certain circumstances but that the main reason was its small size; it was stated that the white colour scheme could also be a factor. Various options were considered and the optimum solution recommended was to fit a collision warning system[6]. The Panel has found no evidence of current work to consider, evaluate or fit a collision warning system to the Tutor aircraft. Annex AG

Meteorological factors

12. **Wind**. The nearest met recording facility to the accident site was MOD St Athan. The surface wind information recorded at MOD St Athan at 1050Z was 280/6 kts. The forecast wind at 3000 ft was 300°/20 kts. Taking into Annex B

[6] The term 'collision warning system' is used throughout to encompass all in-cockpit electronic aids to provide traffic information, alerting and avoidance cues.

consideration the reports from aircrew that had flown in the area that morning and the actual weather observation at MOD St Athan at the time of the accident, the Panel concluded that the wind direction and strength were not factors in the accident.

13. **Turbulence/Windshear**. No turbulence or windshear was forecast or observed during the period or at the time of the accident. The Panel concluded that wind shear or turbulence were not factors in the accident. Annex B

14. **Visibility**. The forecast visibility for the local flying area was 15 km improving to 25 km by 1200Z. Evidence from pilots who flew in the local area immediately prior to the accident sorties confirmed that the visibility was good. Most eye-witnesses also described the visibility as good although 2 added that there was some light haze. Taking into account the accident location, forecast weather condition, reports from aircrew that had flown in the area that morning and photographic images taken by the SW Police ASU, the Panel concluded that visibility was good in the immediate vicinity of the accident and was not a factor in the accident. Annex B Witness 1, 2

15. **Cloud**. Photographs taken by the SW Police ASU within 30 mins of the accident show good visibility in the local area with predominantly clear sky to the west and SCT high level CI cloud. However, photographs taken pointing towards to the north and east of the local flying area show that the higher ground area between Maesteg and Bridgend was covered with low level SCT SC up to 3000 ft against a backdrop of high level SCT CI at 18000 ft. Noting the Tutor paint scheme and the poor contrast that may result from a backdrop of cloud, the Panel considered that cloud was a probable contributory factor. Annex B Annex Q

16. **Glare**. At 1046Z on 11 Feb, the sun's elevation at the accident sight, near Kenfig, was 20.9° above the horizon on a bearing of 153.1° from true north. Following departure from MOD St Athan, both aircraft flew west to Nash Point and then north west towards North Cornelly. During this phase the sun was to the left of each aircraft and the Panel concluded that this would not have impeded normal lookout by either pilots. During the final 40 secs of flight the pilot of G-BYUT completed a left turn through approximately 270° and would have been pointing directly into sun with 30 secs to impact. During the final 20 secs prior to impact the sun was behind aircraft G-BYUT and the Panel concluded that this would not have affected the pilot's ability to visually acquire G-BYVN. During the last 40 secs of flight, the pilot of G-BYVN was in a climb with the sun on his left. Approximately 30 secs prior to impact the pilot of G-BYVN turned left onto a westerly heading which put the sun into his approximate 9 o'clock position. The final approach of G-BYUT towards collision with G-BYVN was from the south and slightly high. The Panel concluded that glare from the sun was a possible contributory factor in the accident. Annex AB Annex E

Aircraft handling

17. **Cadet input**. Both ATC cadets were on their first Tutor sortie and had been briefed in accordance with TGO(E) 365. Due to the absence of a cockpit voice recorder (CVR), the Panel had no record of in-cockpit events for either aircraft. The Panel postulated that each captain would have been expected to follow the guidance within TGO(E) 365 in terms of sortie content, pointing out local features, demonstrating gentle aerobatics by request, allowing each cadet to follow through on the aircraft controls, and possibly allowing the cadets to take control of the aircraft under supervision. It was not possible to determine who was flying each aircraft immediately prior to the collision but the Panel did Annex I

not consider that this would have had a bearing upon the accident as the aircraft captains were still responsible for the safety and conduct of the flights. The Panel concluded that control inputs by the cadets could not be discounted but were unlikely to have been a factor.

Pilot incapacitation

18. The Panel considered whether either pilot may have been incapacitated in the moments prior to the collision. Possible causes of incapacitation include inhalation of CO fumes or the onset of a medical condition. The CO detector in G-BYUT was recovered from the ground impact site and although it did not indicate the presence of CO the Panel learned that the detector will revert to a normal indication once removed from CO; it was not possible to determine whether CO was or was not present in the pilot due to his injuries. The CO indicator from G-BYVN could not be found and was presumed destroyed by fire but the post-mortem report indicated that the pilot was not suffering from the effects of CO or any other toxin. Both pilots were in date for their annual aircrew medicals and were reported as being in good health. Both aircraft were reported as approaching the collision point in steady flight and the Panel concluded that the aircraft were therefore under control and that pilot incapacitation was not a factor in the accident.

Witness S121

S7,S9,S10,S13, S27,S70

Survivability

19. The Panel had very few facts upon which to draw conclusions. It was not possible to determine whether any of the occupants of G-BYUT or G-BYVN were injured or incapacitated during the mid-air collision. Nevertheless, by assessing the radar trace data, eyewitness accounts of aircraft behaviour post collision, a QinetiQ analysis of expected post collision aerodynamic forces, the known condition of AEA and SE post ground impact, and technical evidence relating to the canopy jettison and operating mechanisms of both aircraft, the Panel was able to draw broad conclusions.

Annex E

20. The transponder return from G-BYUT at 1046:44[7] was 2800 ft Mode S and the Panel assessed that this was the best indication of the collision altitude, based on the International Standard Atmosphere (ISA) datum of 1013 mb. The local barometric pressure (QNH) on 11 Feb 09 was 1018 mb giving a height of 2650 ft above mean sea level (amsl). The mean elevation of both main accident sites is 88 ft giving a collision height of 2562 ft above ground level (agl). The normal recommended minimum abandon height (MAH) for the Tutor is 1500 ft agl and the parachute manufacturer specifies a Minimum Parachute Operating Height (MPOH) of 500 ft agl. Post-collision, this would have given all occupants a maximum of 1062 ft above the normal Tutor MAH and 2062 ft above the minimum parachute operating height. However, the Minimum Abandon Height (MAH) used during spinning, which generates a high rate of descent, is nominally 3000 ft agl[8]. The manufacturer's MPOH takes no account of an initial rate of descent and assumes that descent is commenced from 500 ft (i.e. zero starting velocity, thereafter accelerating at 9.81 ms^2 through the effect of gravity).

Annex E

Annex I

Annex AU

21. The Panel assessed the limited altitude data from the few post-collision radar returns (one return for G-BYUT and 2 for G-BYVN) to determine the time available to the occupants of each aircraft post collision. Calculations alone,

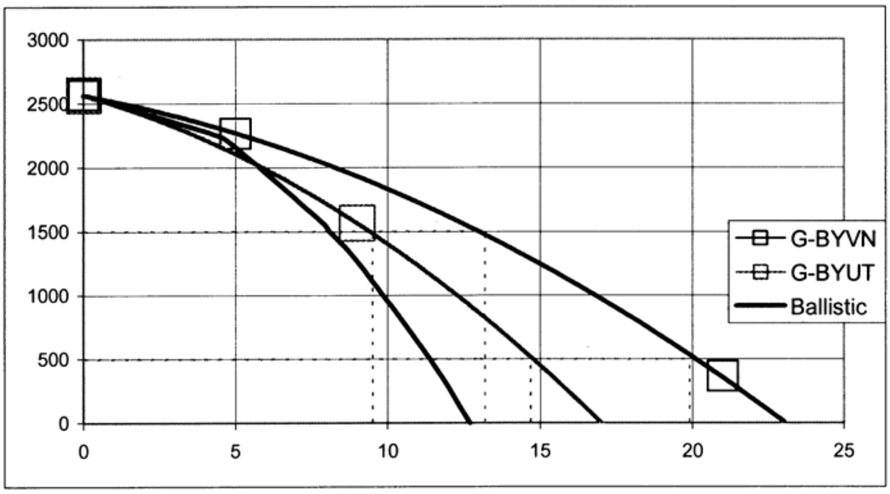
Annex E

[7] Unless specified, all radar trace data times are referenced to Cardiff radar.
[8] MAH for spinning is calculated by adding the height of the terrain being overflown to the Transition Level (nominally 3000 ft amsl but which caters for variations in the ambient air pressure).

based upon the mathematical equations of motion, provide a misleading degree of accuracy and the Panel concluded that there were too few data S70, S50 points to have confidence in this approach, especially given the extent of unknown factors, such as velocity vectors post-collision, precise time of collision, total drag and transponder accuracy[9]. The Panel therefore compared the transponder returns with a graphical representation of a purely ballistic trajectory and used this approach to develop a descent profile that matched the known data and interpolated the derived graph to estimate the time of descent for each aircraft. The graph (Figure 1) suggests that G-BYUT reached the ground after no more than 17 secs while G-BYVN impacted the ground after a maximum of 23 secs. Eye-witness accounts describe G-BYUT as impacting the ground before G-BYVN.

[9] The Tutor transponder derives an altitude input from an encoder within the main instrument cluster. The altitude encoder receives a pressure feed from the static vents on the aft fuselage, which were compromised on G-BYVN. In the absence of a static pressure feed, the transponder will use ambient cockpit pressure but this is likely to be affected by a compromised canopy.

Time	Ballistic	G-BYUT	G-BYVN
0	2562	2562	2562
4.3	2262		
5	2160		2262
7.9	1562		
8.1	1500		
9	1270	1562	
11.4	500		
12.7	0		
21			362

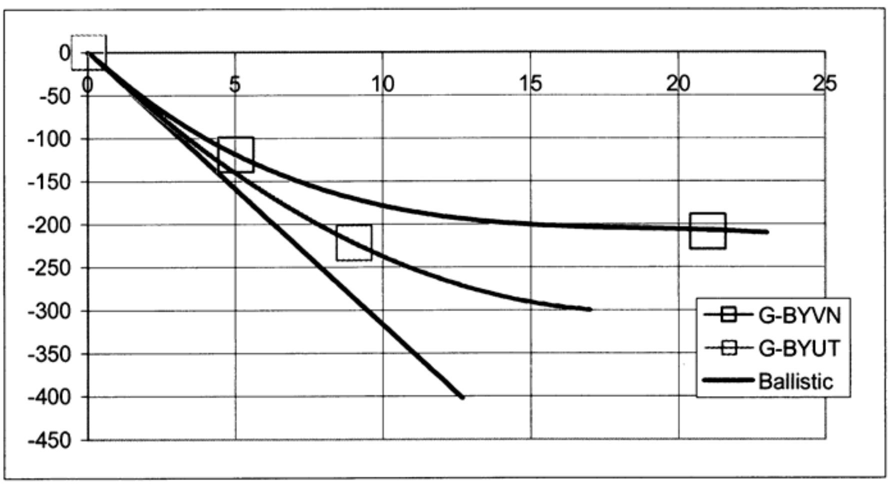


Height vs Time

Time	Ballistic	G-BYUT	G-BYVN
0	0	0	0
4.3	-136		
5	-158		-120
7.9	-250		
8.1	-257		
9	-285	-222	
11.4	-361		
12.7	-402		
21			-210

Conclusions:
G-BYUT passed 1500 ft after 9 secs, with ROD 240 fps.
G-BYVN passed 1500 ft after 13 secs, with ROD 190 fps.
G-BYUT passed 500 ft after 15 secs, with ROD 280 fps.
G-BYVN passed 500ft after 20 secs, with ROD 200 fps.
G-BYUT impact after 17 secs, with ROD 300 fps.
G-BYVN impact after 23 secs, with ROD 210 fps.

CAVEAT: All figues are estimates based upon limited data.



Rate of Descent vs Time

Figure 1. Graphical estimation of the post collision descent profiles.

22. Using the graph of the most likely descent profiles, the Panel concluded that the occupants of G-BYUT would have reached the MAH after only 9 secs

and had no more than 15 secs following the collision to abandon the aircraft and deploy a parachute at or above the minimum operating height of 500 ft agl. The occupants of G-BYVN would have reached the MAH after around 13 secs and had no more than 20 secs following the collision in which to deploy a parachute above the MPOH (Figure 2). To assess the survivability of this timeline, the Panel considered post-collision pilot response, aircraft aerodynamic behaviour, pilot decision making, egress and parachute drills and AEA/SE.

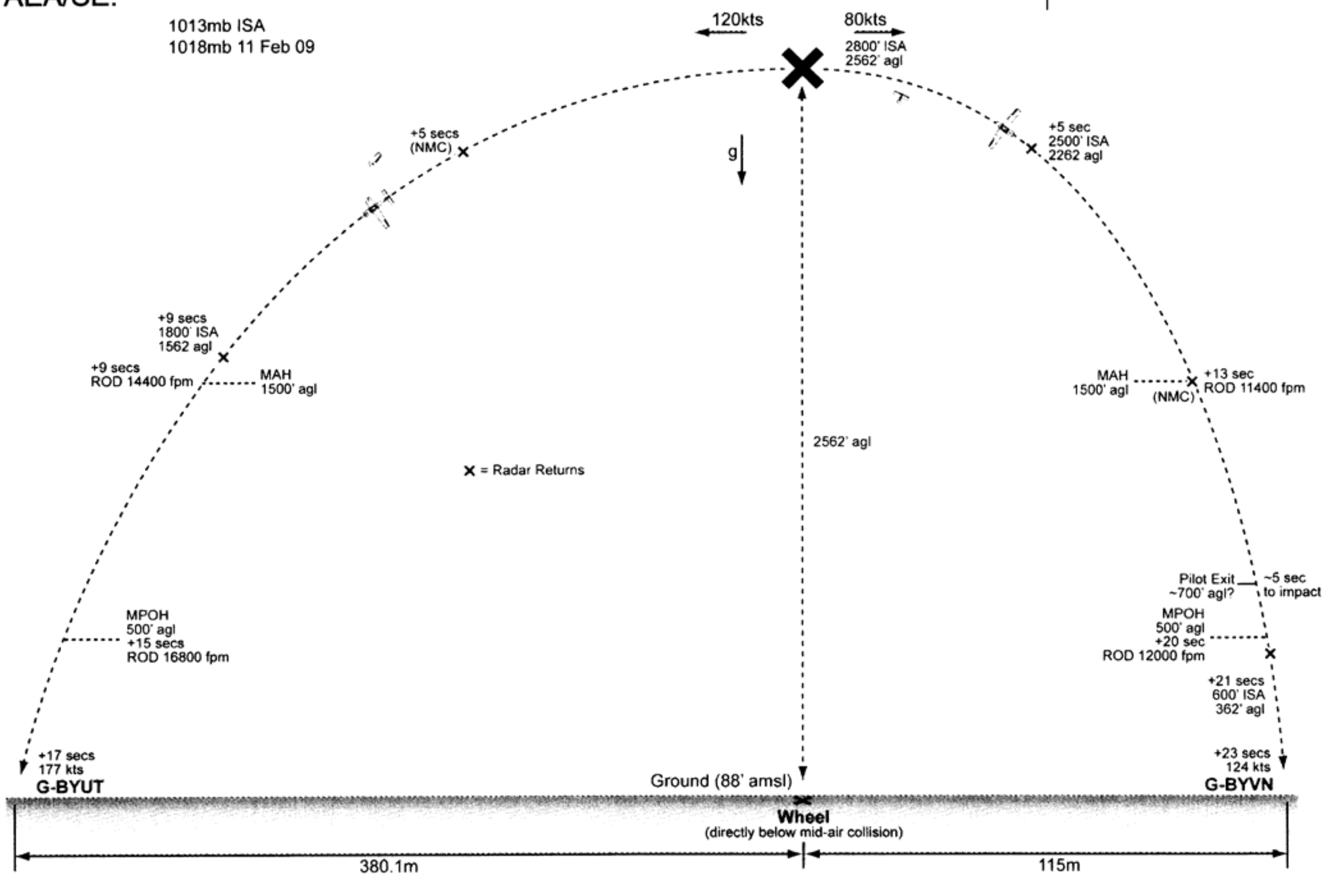


Figure 2. Illustration of radar returns and estimated descent profile post collision.

23. **Post-collision pilot response**. The response of each pilot is likely to have been dependant on whether the collision was expected or unexpected. The Panel was unable to determine whether either pilot had seen the other aircraft at a very late stage. One witness described G-BYVN as pulling up immediately prior to collision but all other witnesses described the flight paths as steady up to the impact point and thus, on balance, the Panel thought it most likely that both pilots were unaware of each other up to the point of collision. The collision orientation, with G-BYUT striking the underside of G-BYVN, should have given the pilot of G-BYUT awareness that he had collided with another aircraft but the pilot of G-BYVN may have been unaware that he had collided even after the event. An unexpected event, especially one with violent and disorientating consequences, could be expected to leave the subject confused for a period of time. Both pilots would have experienced uncommanded aircraft movement and the Panel considered that the most likely immediate response would have been an attempt to regain control, especially if the pilot was unaware of the extent of the structural damage sustained, noting that the pilot of G-BYVN might not have been immediately aware that his tail section had detached. The post-collision behaviour of G-BYVN (described by most eye-witnesses as an initial rotating manoeuvre) may have prompted the pilot to attempt spin recovery action. The structural damage to the lifting surfaces of both aircraft was catastrophic and would have

S27

Annex AF

Witness S7,S9,S10,S14, S27,S31,S36,S70

Annex K

rendered both aircraft uncontrollable. The Panel could not establish how long it took each pilot to determine that they had no effective control but considered that it could be expected to have consumed at least several seconds. If an estimate of 3-5 secs is made then, at best, only 10-12 secs (G-BYUT) and 15-17 secs (G-BYVN) would remain in which to decide to abandon the aircraft, effect egress and deploy a parachute before reaching the MPOH.	
24. **Post-collision aircraft aerodynamic behaviour**. The Panel commissioned QinetiQ to provide an estimate of the aerodynamic behaviour of G-BYUT and G-BYVN post-collision, to include an estimate of the time taken to reach the ground. Their assessment was based upon a brief that G-BYUT lost its starboard wing in the collision and that G-BYVN lost its tail, with accompanying pictures of the aircraft wreckage. QinetiQ staff were not briefed or given access to any witness statements and their report therefore provides a useful, independent means to compare with the eye-witness statements and radar data.	Annex AF
a. **G-BYUT**. QinetiQ assessed that, post-collision, G-BYUT would have been subject to a large right rolling moment from the remaining wing and that the aircraft may have continued in a tight spiral descent to the ground. There would also have been a left yawing moment from the unbalanced drag on the left side. The aircraft would have been rotating about a new centre of gravity (CG) position displaced to the left of the centreline which may have resulted in unusual centrifugal accelerations, particularly affecting the occupant of the right hand seat, which would have been very disorientating. It was unlikely that G-BYUT would have lost altitude at a rate less than an average of 6000 feet per min (fpm) which would have led to the aircraft reaching the ground after about 17 secs. The QinetiQ assessment closely matches the observations of the eye-witnesses and the limited altitude data from radar, giving the Panel increased confidence that the post-collision behaviour of G-BYUT was broadly understood.	Annex AF S7,S9,S10,S27, S31,S70
b. **G-BYVN**. After losing its tail in the collision, QinetiQ assessed that G-BYVN would have experienced a violent nose down bunt due to the absence of the normal tailplane download and the forward movement of the CG. The airspeed would have rapidly reduced to near zero and thereafter entered some sort of rotational descent. It was not possible to be precise about the nature of this rotation but any airflow over the wing would have generated an additional nose-down pitching moment. The assessment for the time taken for G-BYVN to reach the ground was 23 secs. The impact site of G-BYVN was almost directly below the point of collision which supports the QinetiQ assessment that the airspeed would rapidly reduce although eye-witnesses did not describe a marked pitch down immediately after the collision. While eye-witnesses may not have noticed or recognised a short duration manoeuvre, the Panel also noted that modelling of the likely aerodynamic behaviour took no account of the forces imparted to each aircraft by collision with the other. The initial rotating manoeuvre described in eye-witness accounts of G-BYVN could have been as a result of the impact forces upon G-BYVN, or could describe the subsequent rotation that the modelling predicts, or might simply have been inaccurate. The Panel also noted that the radar returns from G-BYVN post collision, though limited, suggested a ballistic path with no appreciable change to the vertical acceleration. If correct, eye-witness accounts of an initial, lower rate of descent would be attributable to the way in which the ballistic path was perceived and not	Annex AF S7,S9,S10,S14, S27,S31,S36,S93, S94,S70

to any residual flight characteristics of G-BYVN; in half the total time of descent (11.5 secs) the aircraft would only lose about a third (810 ft) of the total height. The modelling predicted that during the final, steep descent, the airspeed would create lift over the wings aft of the CG and cause the aircraft to pitch further forward towards an inverted attitude. This would be opposed by the weight of the engine and cockpit which would tend to return the attitude to 90° nose down, perhaps leading to a swinging motion.

25. **Abandon decision**. The Panel concluded that it was likely that both pilots had made a decision to abandon the aircraft as evidenced by both having released their seat harnesses prior to ground impact. It was not possible to determine if either pilot had attempted to assist their cadet during the descent, post collision, but the Panel felt that both pilots would have been very aware of their responsibility to them. It is unlikely that the cadets, when confronted with such an extreme situation, would have been able to react effectively, unaided, in the timescale available; this assertion is supported by the condition of their harnesses which remained locked upon impact with the ground. The actions of the pilots will never be known but the Panel opined that the dilemma that they faced could reasonably be expected to have at least delayed any decision making process, consuming valuable seconds.

26. **Egress drills**. In order to understand better the time required to egress from the Tutor aircraft as compared to the time available, the Panel observed and timed an egress drill from a UWAS pilot. While this cannot be regarded as a full trial, the Panel considered that any delay to investigating egress procedures would compromise the validity of results as Tutor pilots gave the drill additional consideration in light of the accident. The Panel therefore sought assistance from a UWAS pilot, ostensibly to assess anthropometric issues, and then asked the pilot to complete an egress drill, albeit by opening the canopy with the normal mechanism, with no more warning than it took to issue the instruction. From issuing the executive command to abandon, it took the pilot just over 6 secs to exit the cockpit and it must be noted that the aircraft was stationary and not subject to disorientating effects, centripetal loads or aerodynamic forces. Of considerable note, a second attempt took a little over 4 secs. The exact sequence of events within G-BYUT and G-BYVN aircraft could not be established but the Panel assessed the few known facts.

Annex Q

a. **G-BYUT**. The windscreen, canopy arch and canopy of G-BYUT were probably damaged in the mid-air collision, most likely by impact with the port main undercarriage leg of G-BYVN. There was very little canopy acrylic (about 32% of the area of an intact canopy) present at the main impact site of G-BYUT, with a great many fragments found in the downwind wreckage trail, and the Panel concluded that the canopy of G-BYUT shattered in the collision. It could not be discounted that the fragments present at the main impact site derived from just one of the 2 panels that comprise the canopy, with one of the panels remaining intact until ground impact; this was considered unlikely given the collision orientation. If the canopy was compromised then the pilot, who was unstrapped at ground impact, could have attempted to exit the cockpit directly but the Panel noted that an attempt had been made to open the canopy. It may not have occurred to the pilot to effect an escape through the canopy but the Panel could not discount a conscious attempt to jettison or open the canopy in order to facilitate the cadet's egress. The MIG report concluded that the canopy operating handle in G-BYUT was likely to

Annex K

Annex J

have been in the canopy unlocked position upon impact with the ground. Furthermore, the end stops displayed witness marks of black paint where the canopy release bracket assembly had contacted the end stops with 'some force', which implies that the canopy operating handle had been pulled to the rear with 'some force' although it could not be discounted that this had occurred prior to the accident. No attempt to pull the emergency jettison handle appeared to have been made. The Panel could not account for the pilot of G-BYUT consciously disregarding the canopy jettison facility, which would entail withdrawing the red jettison handle before operating the canopy opening handle. It appears likely that under the stressful conditions prevailing that he instinctively employed the method for opening the canopy with which he was most familiar and immediately operated the normal canopy opening handle, amounting to a cognitive error which resulted in performing the incorrect drill. The damage sustained by the canopy in the collision may have impeded or prevented any attempt to open it normally.

b. **G-BYVN**. Eye-witness accounts describe a person or object separate from the aircraft in the latter stages of the descent and the pilot was found 23m from the main impact site. The canopy of G-BYVN was closed and locked at ground impact and no attempt appeared to have been made to operate either the emergency jettison handle or normal opening mechanism. Photographs of G-BYVN taken very shortly after ground impact indicate that there were no obvious breaches of the underside of the aircraft in the region of the cockpit structure large enough for the pilot to have passed through. Fragments of canopy acrylic were present at the ground impact site of G-BYVN but most of the aircraft had been consumed by fire. It was not possible to identify from which aircraft the acrylic fragments within the downwind debris field had originated and while there were insufficient pieces to account for an area greater than a single canopy and thus they could have all originated from G-BYUT, the Panel nevertheless considered it likely that the canopy of G-BYVN was also compromised during, or shortly after[10], the mid-air collision and that this provided the route through which the pilot left the cockpit. The Panel was unable to determine whether the pilot of G-BYVN had deliberately abandoned the aircraft or had been thrown clear by the forces acting upon it when he released his seat harness, noting the evidence to suggest that the aircraft may have been subject to a bunting force.

Witness S7,S9,S17 S27,S29,S30,S31, S33,S34,S44,S58, S70

Annex Q

Annex K

Annex AF

27. **Parachute drills**. From eye-witness accounts, the Panel developed a best estimate of 700 ft agl for the height at which the pilot of G-BYVN separated from the aircraft, but considered that this was still very subjective and unlikely to be entirely accurate. If accurate, an egress at 700 ft would have been 200 ft above the nominal MPOH but would only equate to about 5 secs before ground impact owing to the high rate of descent (around 12 000 fpm). Nevertheless, the parachute is designed to inflate within 2 secs and would therefore have been effective if deployed by 500 ft although the pilot would only have had 1 sec to achieve this, after which the parachute was unlikely to successfully arrest descent. Overall, the Panel considered that 5 secs should have permitted the pilot to at least initiate parachute deployment and therefore considered the factors that may have prevented this, which

Witness S7, S27,S31,S34,S44, S70

[10] It is possible that a violent bunt, as predicted by the QinetiQ aerodynamic report, could have thrown the pilot against the canopy, even though fully restrained, with sufficient force to shatter the canopy although there were no witness marks on his helmet to support this.

include:

a. **Incapacitation**. Noting that the flight path of G-BYVN was likely to be unstable, it could not be discounted that the pilot was incapacitated or otherwise injured during the egress. Eye-witness accounts were inconclusive but they were no obvious signs of injury that were not attributable to impact with the ground and might indicate an injury sustained during egress. Based upon the evidence that he had unfastened his seat harness, the Panel concluded that the pilot was conscious as he began to leave the cockpit and in the absence of evidence to suggest injury during egress, considered it likely that he was still conscious after exit. Annex M

b. **Surprise**. Taking HF advice, the Panel agreed that 5 secs should have permitted an alert individual to make an attempt to deploy the parachute. An attempt to locate, grasp and pull the parachute handle, under pressure and in a short period of time, would be far more likely to be successful if it was an intended and anticipated event, such as the action to be performed subsequent to a planned abandonment of an aircraft. If the pilot of G-BYVN separated from the aircraft involuntarily as a result of the forces acting upon the aircraft, either immediately upon releasing his harness or while focusing upon a different task (such as attempting to jettison or open the canopy) then it would take time to become orientated to the change of circumstances. As it seems that the pilot had elected to abandon the aircraft, involuntary separation should not have compromised the elements of his plan but would have compromised its execution, by disrupting the expected sequence of actions. He would also have been less well prepared physically, being denied the opportunity to pre-locate the parachute handle before entering freefall. The Panel concluded that involuntary separation from the aircraft could compromise the chances of successfully operating the parachute handle in the short time available and, if the aircraft was subject to a bunting force as modelling predicted, considered that this was likely. Annex AE

c. **Location of parachute operating handle**. The operating handle of the EB85 parachute worn by RAF Tutor pilots is high on the right shoulder strap. The Panel noted that the handle is difficult to see when wearing an LSJ as the stole partially obscures the handle. Slipstream effects would further compromise attempts to acquire the handle visually and the action of locating it, grasping it and pulling it would effectively have to be performed 'blind'. Noting that dexterity would be compromised by slipstream effects and tactile feedback impaired by slipstream and gloves, the Panel concluded that it could take several attempts to locate the parachute handle unless the drill and motor actions were thoroughly and routinely rehearsed.

d. **Parachute training**. RAF Tutor QFIs and EFT students practise parachute drills once during their initial groundschool at RAF Cranwell, to include pulling the handle while suspended in a training rig. Not all AEF units have access to these training facilities or qualified Physical Training Instructors and their familiarity with the parachute is therefore limited to a static demonstration; the critical act of locating and pulling the Tutor parachute deployment handle is not practised during recurrent training. The Panel considered that the chances of correctly and successfully completing an unfamiliar drill, without delay, while disorientated, and with the shock of sudden exposure to a Annex I substantial slipstream and aerodynamic effects, were limited. These conclusions are supported by evidence taken from a serving RAF pilot with experience of successfully abandoning a Firefly that failed to recover from a spin during his flying training. He confirmed that he had encountered difficulty in locating the handle and that he was unfamiliar with the extent to which it had to be pulled to initiate parachute deployment. The Board of Inquiry into the Firefly accident recommended that student pilots receive more detailed training on aircraft SE. The Panel concluded that the current Tutor parachute training would not fully prepare someone for the scenario experienced in this accident and was an aggravating factor in the accident. Witness 17 Annex AT

The Panel concluded that circumstances conspired to prevent the pilot of G-BYVN from successfully locating his parachute handle and initiating parachute deployment. If the height of separation was less than the estimated 700ft, which is entirely possible, then the chances of success would reduce further.

28. **Aircrew Equipment Assemblies and Survival Equipment.** RAFCAM carried out a detailed analysis of the AEA and SE.

a. **G-BYUT**. All of the equipment worn by the pilot was damaged at ground impact but detailed examination did not revealed any pre-impact unserviceabilities. The pilot's aircraft harness buckle was found in the unlocked position, his parachute was in a complete and packed condition and the operating handle had not been operated and was within its fabric housing. Similarly, the equipment worn by the cadet was extensively damaged as a result of ground impact but no pre-impact deficiencies were evident. The aircraft harness was in the locked position and the parachute was also complete and in a packed condition. The cadet's parachute operating handle had not been operated and was within its fabric housing. Annex M

b. **G-BYVN**. The majority of equipment worn by the pilot showed damage consistent with ground impact. Detailed examination of all equipment did not reveal any pre-impact unserviceabilities. Witness marks on the helmet shell matched the profile of the visor and it is likely that the tinted visor was in the raised position at ground impact. The pilot's aircraft harness buckle was in the unlocked position and his parachute was intact and had not been operated. The operating handle of the pilot's parachute was subsequently pulled under test conditions at RAFCAM and the parachute deployed normally. The majority of equipment worn by the cadet was extensively damaged by the post impact fire but the aircraft harness buckle was still fully locked and the parachute operating handle was relatively well preserved with the pattern of heat damage and burning indicating that the parachute handle had not been operated. Annex M

c. **Aircrew Corrective Flying Spectacles**. The pilot of G-BYUT was issued with Corrective Flying Spectacles. A photograph, taken by an air cadet Civilian Instructor of the pilot seated in G-BYUT immediately prior to the accident flight on 11 Feb 09 shows him wearing Corrective Flying Spectacles. A pair of service issue Corrective Flying Spectacles was found in the wreckage of G-BYUT and the Panel concluded that, in all probability, the pilot wore his issued spectacles for the duration of the accident flight. Annex Q Annex M

29. **Summary of survivability conclusions**. After the mid-air collision both aircraft experienced uncommanded manoeuvre and high rates of descent and it took G-BYUT approximately 9 secs and G-BYVN about 13 secs to reach the normal minimum abandon height. For the pilots, the combined effects of shock, uncommanded manoeuvre and disorientation, possibly hesitation regarding the presence of an unresponsive cadet, and a lack of practised familiarity with abandon drills should not be underestimated. For the cadets, the shock and confusion alone would have most likely overwhelmed them and their smaller stature and lower strength may have been inadequate to overcome the forces acting upon them. Overall, it is quite likely that successful abandonment was not realistically possible in the height and time available. The Panel noted that the minimum abandon height for spinning on 11 Feb would have been 3500 ft and under the circumstances of this accident (collision at 2562 ft) only a very swiftly executed abandon decision and drill would have afforded any chance of survival. It seems that the pilot of G-BYUT commenced an abandon drill but was unable to leave the cockpit in the time available. The pilot of G-BYVN also commenced an abandon drill but left the cockpit directly through the canopy, possibly unexpectedly. His parachute was serviceable but the pilot was unable to operate the parachute handle in the time available to him. The Panel concluded that there was possibly a very narrow opportunity to abandon the aircraft and successfully deploy a parachute but the pilots and cadets were not able to exploit this on 11 Feb 09.

Annex E

Annex I

Analysis of Human Factors

Aircraft separation

30. **Deconfliction**. Separation between aircraft[11] flying under VFR in Class G[12] airspace is routinely predicated upon the 'See and Avoid' system, whereby pilots are responsible for searching for traffic that could result in a flight path conflict and, if necessary, manoeuvring to achieve safe separation. UK Air Traffic Services Outside Controlled Airspace (ATCSOCAS) are provided by many civilian and military Air Traffic Service (ATS) providers to a variety of Air Traffic users including military pilots. Controllers endeavour to provide the service that a pilot requests but finite ATS resources or controller workload may influence ATS availability or its continued provision. On 11 Feb 09, G-BYUT and G-BYVN were operating to the west of Cardiff airport and, although a radar service was available, both pilots elected to operate under VFR; no additional procedures to address deconfliction in the operating area at MOD St Athan are mandated. The Panel noted that all HQ 1 EFTS Tutor units including RAF Cranwell, the HQ of CFS, EFT, AEF and UAS training, also operate routinely without additional deconfliction measures in VFR conditions. Arrangements are sometimes implemented informally to cater for marginal weather conditions or established between individual pilots depending upon personal preference, experience or consideration of the risk. The Panel discovered no evidence to indicate that informal arrangements were discussed between the pilots of G-BYUT and G-BYVN, although it could not be discounted. If additional deconfliction arrangements were agreed then they were evidently not adhered to and, on balance, the Panel concluded that this was not the case and each pilot was relying entirely upon the 'See and Avoid' principle. The panel concluded that reliance upon See and Avoid as the primary deconfliction measure was a contributory factor.

Annex AI

Witness 2

[11] To include General Aviation (privately-owned, civilian aircraft) and military traffic.
[12] Class G airspace is the least restrictive and accounts for the majority of airspace within the UK; flights may be IFR or VFR and ATC separation is not routinely provided. Traffic Information may be given as far as is practical.

31. **Situational Awareness**. G-BYUT and G-BYVN were at the holding point together prior to departure and then took-off with one minute's separation. Standard radio calls during the departure profile would have reinforced the awareness of each pilot that the other aircraft would be operating in the same general area. Furthermore, the Panel considered that the pilot of G-BYUT should have known that G-BYVN was between 1 and 2 miles astern and that the pilot of G-BYVN should have been similarly aware that G-BYUT was ahead. The Panel therefore contemplated why the pilot of G-BYUT turned back into the general area from which G-BYVN might be expected to be arriving without positively establishing its position or height to ensure that separation was maintained. The Panel considered that the manoeuvre might indicate a deliberate attempt to reduce separation for the purpose of effecting an intercept or join up but found no evidence to support this. When considering the sortie duration and the limited airspace available, the Panel concluded that the manoeuvre was prompted by a need to remain within a suitable operating area and range of MOD St Athan. The Panel found no evidence that either radio had been used to enhance the Mental Air Picture[13] of either pilot and concluded that this reflected a complete reliance by both pilots upon the effectiveness of 'See and Avoid' as a means to achieve and maintain separation. The Panel concluded that both pilots had an incomplete or incorrect Mental Air Picture of the position, proximity and track of the other aircraft and that this was a contributory factor.

Annex D

Annex E

The See and Avoid principle

32. In order for the See and Avoid principle to be effective, at least one pilot within a conflicting pair must see the opposing aircraft, recognise the threat and then determine and execute an effective avoidance manoeuvre. In the circumstances of this accident, it is self-evident that neither pilot was able to complete this sequence of actions successfully. In attempting to determine the reasons for this, the Panel examined all elements of the See and Avoid principle.

Human Factors affecting the ability to 'See'

33. **Lookout**. In order to visually acquire another aircraft a pilot must, in the first instance, physically direct the eyes' line of sight outside of the cockpit environment and search the volume or airspace surrounding the aircraft. This does not come naturally and must compete with the requirement to scan aircraft systems and instruments within the cockpit. If the search for other aircraft is not systematic, large volumes of airspace will not be scanned frequently enough or at all.

a. **RAF lookout training**. The importance of maintaining a good lookout is introduced early within RAF flying training and the discipline is reinforced throughout flying training and operational service. Some of the physiological limitations of the human visual system are addressed during attendance at RAFCAM at RAF Henlow and AP3456 provides an overview of the human eye. Practical advice as to how to execute a lookout scan is contained in Volume 1 of the Tutor Training

[13] Mental Air Picture is the mental model that pilots construct to assist their 3-dimensional orientation to other aircraft; it is often associated with a tactical disposition of forces but also has routine application to either maintain separation on traffic or effect formation rejoins. Mental Air Picture can be regarded as a subset of Situational Awareness which aims to embrace all factors pertaining to a flight, such as fuel state compared to location, weather, and local orientation to airspace, hazards, diversions, etc.

[14] A précis of this advice is contained within Volume II of the Tutor Training Manual, the Student Study Guide, at page 6.6, para. 21.

Manual, the Flying Instructors Handbook[14].

13. **Maintaining Straight and Level Flight.** Teach the student how to maintain straight and level flight whilst maintaining a good lookout. The 'Lookout - Attitude - Instruments' scan should be taught as follows:

a. **Lookout.** Lookout to the front and scan above and below the horizon, then check attitude and instruments, correcting if required. Move the eyes around the horizon in a series of steps (normally to the right initially), scanning up then down at each point (consider introducing the clock code to ensure that the student stops his scan regularly). Emphasise that it is essential to stop the eyes to make relative movement of other aircraft evident and point out that, when looking into the 3 o'clock, the wingtip spacing can be checked to confirm that the wings are still level. Brief the student to hold the control lightly or to lock his arm against his body or the side of the aircraft so that the attitude is not disturbed when looking out to the rear. Continue the scan back to the tailplane and then look above and behind over the top and back to the front.

b. **Attitude.** Check the attitude and, if it has changed, reselect.

c. **Instruments.** Check the instruments (HSI, altimeter and slip ball). If necessary re-achieve straight and level flight and retrim.

d. Continue the scan by looking to the front and then scanning on the other side above and below the horizon, again in a series of steps, back to the tailplane and then look above and behind over the top and back to the front.

Figure 3. Extract from Tutor Training Manual.

34. **Arousal levels.** Both pilots were familiar with AEF and local procedures, neither of which would have presented difficulties for them, and the Panel did not therefore consider that either pilot would have found the workload high enough to preclude devoting adequate time to lookout. The Panel also considered the possibility that either pilot allowed their concentration to lapse as a result of low arousal levels. The AEF profile, while benign, is nevertheless subject to constant change as a result of the limited sortie time allotted to each detail. After departure and recovery are allowed for, barely 10 mins remain to achieve the principal aims of the sortie; these will vary according to cadet experience and the determination of the cadet passenger's enthusiasm, appetite and ability are a part of the challenge. Having established that the pilots enjoyed their duties and were in good spirits on 11 Feb 09, the Panel concluded that the tempo of the sortie would have permitted little opportunity for arousal levels to drop and did not therefore consider arousal levels, either low or high, to have been a factor. Witness 1

35. **Limitations of the human visual system.** Even when pilots are looking out there is no guarantee that other aircraft will be detected. An aircraft, especially when approaching head-on and thus presenting minimum aspect, can subtend an angle that is below the acuity threshold of the human eye until a surprisingly short time before a prospective collision. The rate of apparent growth of a target aircraft's size is not linear and, even at combined closing speeds of less than 200 knots, only 'blooms' appreciably in the final seconds before the point of closest approach, or collision (Figure 4).

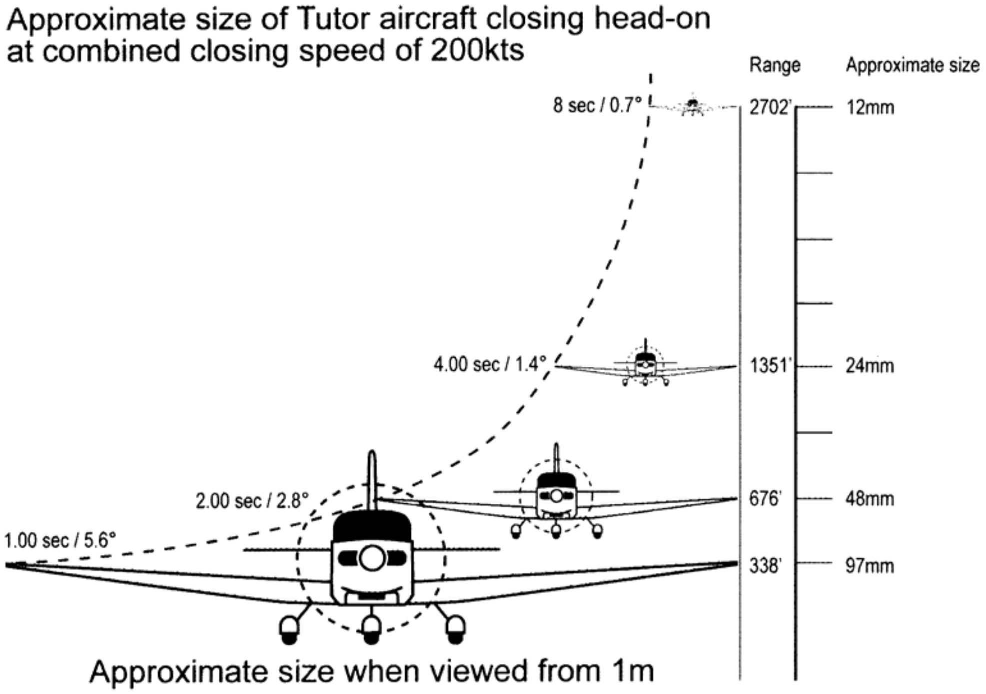


Figure 4. Diagram showing rate of growth of Tutor aircraft closing head-on.

Even if physically detectable, the indistinct shape that is often apparent at ranges required to resolve flight path conflicts may not be readily distinguished from its background or not immediately recognised as an approaching aircraft.

a. **Visual acuity**. The quality of vision varies across the visual field, largely in accord with the distribution on the retina of the two types of light sensitive cells, rods and cones[15]. Acuity in daylight reduces dramatically away from the direct line of sight and a pilot must therefore look at or near a target to have a good chance of detecting it, as illustrated in Figure 5.

Annex AD

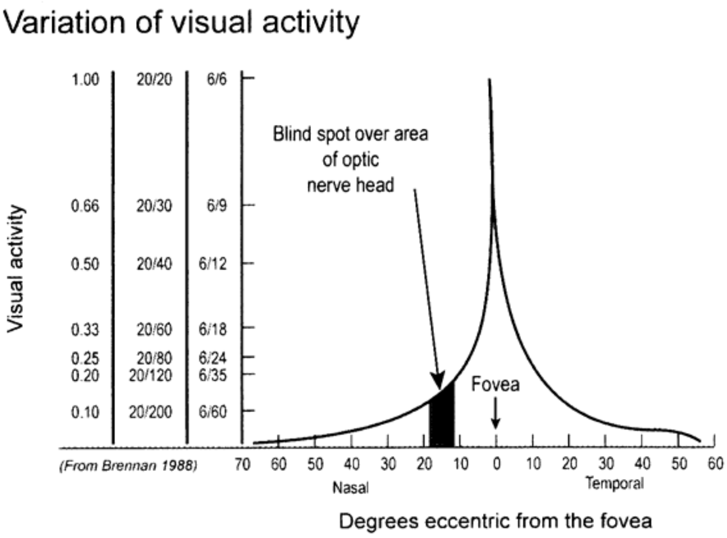


Figure 5. Performance of the human eye – visual acuity.

[15] Cones provide sharp vision and colour perception in daylight illumination and are concentrated at the fovea, the central part of the retina on which an object appears if it is looked at directly. Rods are situated on the remainder of the retina surrounding the fovea on an area known as the peripheral retina. In daylight, acuity (sharpness of vision), colour perception and the detection of slow movement are best at the fovea, while detection of rapid movement is best in the periphery.

The acuity actually achieved is further affected by reflectance and transmission losses due to having to look through transparencies, typically at least one visor and the aircraft canopy. If clean and unscratched then these losses should be minimal but they will inevitably compromise unimpeded acuity to a small degree.

b. **Detection of objects**. The human visual system is better at detecting moving targets than stationary targets, yet in most cases, an aircraft on a collision course appears as a stationary target in the pilot's visual field. Peripheral and foveal vision each perform different functions when performing a visual search. A moving object will generally be detected in peripheral vision first but must be fixated on the fovea (central part of the retina) before identification can occur. When performing a systematic search for traffic, the eye moves in a series of rapid jerks called saccades, interposed with brief rests called fixations. It is not possible to move the eyes smoothly across a scene unless a moving object is being tracked and the human eye only detects detail during the fixations, being effectively 'blind' during the saccades. Insidiously, the human brain compensates for the saccades during a scan to create the perception that a scene is being scanned smoothly; thus, without education, it is not apparent that elements from a scene are being missed. Annex AD

c. **Blind Spot**. The human eye has a blind-spot at the point where the optic nerve exits the eyeball. Under normal conditions of binocular vision the blind spot is not a problem as the area of the visual field falling on the blind spot of one eye will still be visible to the other eye. However, if the view from one eye is obstructed then objects in the blind spot of the remaining eye will be invisible. This phenomenon is insidious as the brain compensates for the blind spot by filling in the missing area from the surrounding scene so the extent of the problem is not readily apparent. The blind spot covers a visual angle of 7.5° vertical and 5° horizontal (Westheimer 1986)[16] which represents an area of around 18 metres in diameter at a distance of 200 metres; the wingspan of the Tutor is 10.0 metres. Since an aircraft on a collision course will appear to be stationary in the visual field, the blind spot could potentially mask an approaching aircraft, especially if vision is limited by obstructions. Annex AD

d. **Field of View**. The average person has a Field of View (FoV) of around 190°, although this varies from person to person and is generally greater for females than males. The FoV begins to contract after about age 35 and, in males, this reduction accelerates after 55 years of age (Leibowitz 1973)[17], with around 10° of arc lost to each eye over the ensuing 10 years (Figure 6). The Panel could not determine whether the FoV of either pilot was a factor in the accident. Annex AD

[16] Referenced on p10 of the Australian Transport Safety Bureau (ATSB) report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.
[17] Referenced on p6 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

Right eye visual field for males and females

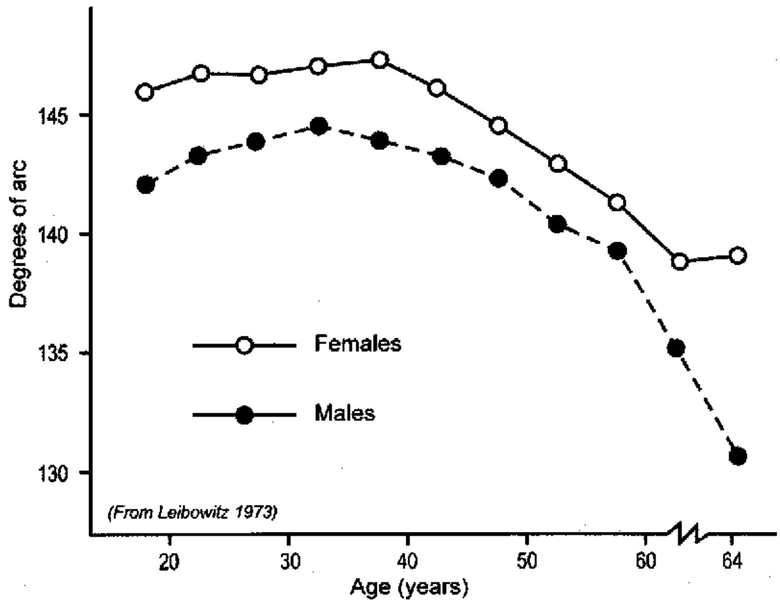


Figure 6. Performance of the human eye – Field of View.

Annex AD

e. **Focus**. The human eye is brought into focus by muscle movements which change the shape of the eye's lens, a process known as accommodation. The time taken to change the focus of the eye generally increases with age and, like all muscular processes, can be affected by fatigue. In the absence of visual cues, the eye will focus at a relatively short distance (in the dark the eye focuses at around 50 cm) and in an empty field such as blue sky, the eye will focus at around 56 cm (Roscoe and Hull 1982)[18]. This effect is known as empty field myopia and can reduce the chance of identifying a distant object. The presence of objects close to the eye's resting focus (or 'dark focus'), such as cockpit structures or marks on the canopy transparencies, can result in another phenomenon known as the Mandelbaum effect, in which the eye is involuntarily 'trapped' at its dark focus of around 50 cm. However, the ability to accommodate to greater distances can be improved by training (Roscoe and Couchman 1987)[19] and both pilots would have been aware of these phenomena from their training and would have practised techniques, such as looking at distant features or the wing-tips, to overcome it.

Annex AD

f. **Corrected vision**. A loss of visual acuity within the eye can be corrected by a lens to restore the focus of images onto the retina. Correction to vision is achieved through the issue of prescribed Corrective Flying Spectacles or approved contact lenses, each of which has advantages and disadvantages. Not all users find contact lenses comfortable to insert or wear whereas Corrective Flying Spectacles are less effective at improving overall vision as visual acuity is inevitably affected by the need to look through another transparent layer which presents another 2 reflective surfaces. In practice, Corrective Flying Spectacle lenses are prone to be further degraded by dust, dirt, sweat

[18] Referenced on p12 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.
[19] Referenced on p12 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

and surface scratches, all of which have an adverse effect upon acuity. The frames of Corrective Flying Spectacles also obstruct peripheral vision and the lenses limit the FoV that benefits from correction; a target aircraft could therefore be obscured by the frames of Corrective Flying Spectacles or lie outside of the corrected FoV and therefore go undetected. The Panel noted the conclusions of a study by the Royal Centre for Defence Medicine (Partner 2005) that Corrective Flying Spectacles are associated with problems in terms of comfort and safety while contact lenses deliver improved visual performance. The Panel also noted that, presently, pilots are permitted to wear contact lenses but must pay for their own which is likely to discourage a great many from procuring and wearing them. Recent changes in Defence Medical Services have withdrawn the previous facility at OASC Cranwell for prescribing contact lenses to aircrew and thereafter monitoring their in-service use. Currently, if aircrew choose to wear contact lenses for flying duties they must source their own, without even the benefit of advice regarding preferred products and suppliers. The Panel were unable to determine if the Corrective Flying Spectacles worn by the pilot of G-BYUT impeded his ability to detect G-BYVN in his peripheral vision and could not discount this as a possible contributory factor.

Annex AJ

36. **Aircraft conspicuity**. Contrast is the difference between the brightness of a target and the brightness of its background and is one of the most significant factors in determining the likelihood of visual acquisition (Andrews 1977, Duntley 1964)[20]. The greater the contrast, the more conspicuous a target becomes. An aircraft colour scheme that increases the contrast will increase conspicuity but this, of course, depends upon the luminance of the background. Against a dull or dark background, such as the predominant terrain in north-west Europe throughout most of the year, a light coloured aircraft will be detected most easily. Against a light background, such as bright sky, a dark aircraft will be most conspicuous. Bright colours, such as fluorescent paint, have been used in the past in an attempt to increase visual conspicuity (Federman and Siegel 1973)[21] but several trials have concluded that fluorescent painted aircraft are not easier to detect than aircraft painted in non-fluorescent colours. Indeed, trials of aircraft detection carried out in 1961 indicated that in 80% of first detections, the aircraft was darker than its background (Graham 1989)[22].

Annex AD

a. **Atmospheric effects**. Even in conditions of good visibility, contrast can still be severely reduced by small particles of water in haze (Harris 1979)[23]. Not only is some light scattered away from the observer but some light from the aircraft is scattered so that it appears to originate from the background, while light from the background is scattered onto the eye's image of the aircraft. Nevertheless, weather conditions on 11 Feb 09 were good with visibility recorded as 10 km.

Annex AD

b. **Effectiveness of Anti-Collision Lights**. The visibility of a light largely depends on the luminance of the background and typical daylight illumination is generally sufficient to overwhelm even powerful strobes. Some typical figures of background luminance are listed within Figure 7.

Annex AM

[20] Referenced on p14 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.
[21] Also on p14 of the above report. Original reference not sourced.
[22] Also on p14 of the above report. Original reference not sourced.
[23] Also on p14 of the above report. Original reference not sourced.

Luminance of common backgrounds Annex AD

Background	Candelas* per Square Metre
Sky	
Clear day	3000.00
Overcast day	300.00
Very dark day	30.00
Twilight	3.00
Clear moonlight night	0.03
Ground	
Snow, full sunlight	16000.00
On sunny day	300.00
On overcast day (approx.)	30.00 to 100.00

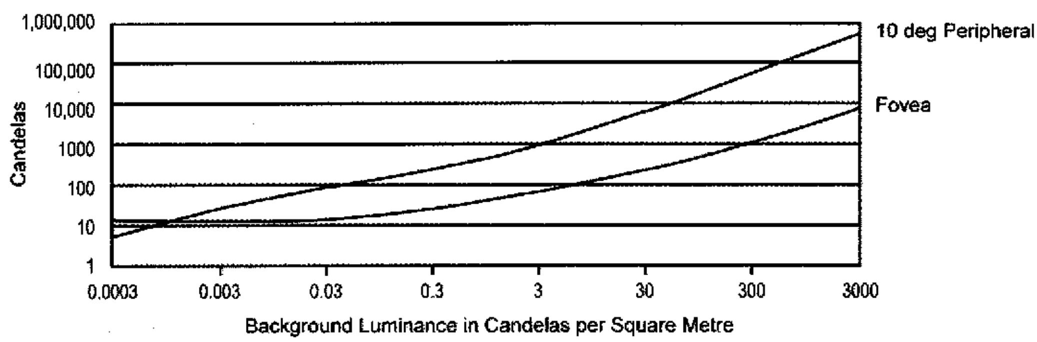
(From IES Lighting Handbook, page 325)

* A candela is approximately equal to a candle power

Figure 7. Background luminance.

The HISLs fitted to the Tutor have an effective intensity of 2000 candelas. However, in theory, to be visible at 3 nm on a very dark day, a strobe light must have an effective intensity of around 5000 candelas (see Figure 8). In full daylight, the strobe must have an effective intensity greater than 100,000 candelas (Harris 1987)[24]. Annex AG

Required effective intensity in Candelas



(From Harris 1987)

Figure 8. Strobe luminance required to be visually significant.

These theoretical results are borne out by field trials in the US which have generally confirmed the ineffectiveness of strobes in daylight, the details of which are attached at Annex AM. Annex AM

The Panel concluded that aircraft conspicuity was a probable contributory factor in the accident.

37. **Obscuration**. Most cockpits have obstructions, such as a canopy arch, which interrupt a pilot's field of view. In response to the Zagreb mid-air collision of 1976, a study investigated the effects of cabin window-posts on the Annex AD

[24] Referenced on p18 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

visibility of contrails (Roscoe, S.N. and Hull, J.C. 1982)[25] and determined that an obstruction wider than the distance between the eyes will not only mask some of the view completely, but will result in certain areas of the outside world being visible to only one eye. A target which falls within such a region of monocular visibility is less likely to be detected than a similar target visible to both eyes.

a. **Tutor Field of View obstructions**. The canopy arch on the Tutor aircraft is particularly wide, significantly worse than the Firefly and the Bulldog for example. Visibility from the Tutor aircraft is further compromised by a substantial spine and canopy handle along the length of the canopy centreline; neither the Firefly nor the Bulldog had such an intrusive limitation to visibility. The imposition of the Tutor canopy arch is further exacerbated by the lack of any 'go-forward' mechanism on the seat harness, such as fitted to the Firefly, which limits the range of movement available to the pilot. The Panel commissioned QinetiQ to map the Field of View (FoV) available to the pilots of G-BYUT and G-BYVN from the best estimate of their sitting heights. Their results are depicted in Figures 9 (G-BYUT) and 10 (G-BYVN), which show the areas that cannot be seen by each eye from any single head position. It is apparent that substantial areas of the external scene can only be brought to bear upon one eye, or not at all (brown shading) despite movement of the head in the attempt to look around cockpit obstructions. Areas in white represent the unobstructed view available to both eyes; note the additional obstruction presented by an adjacent passenger. Annex AH

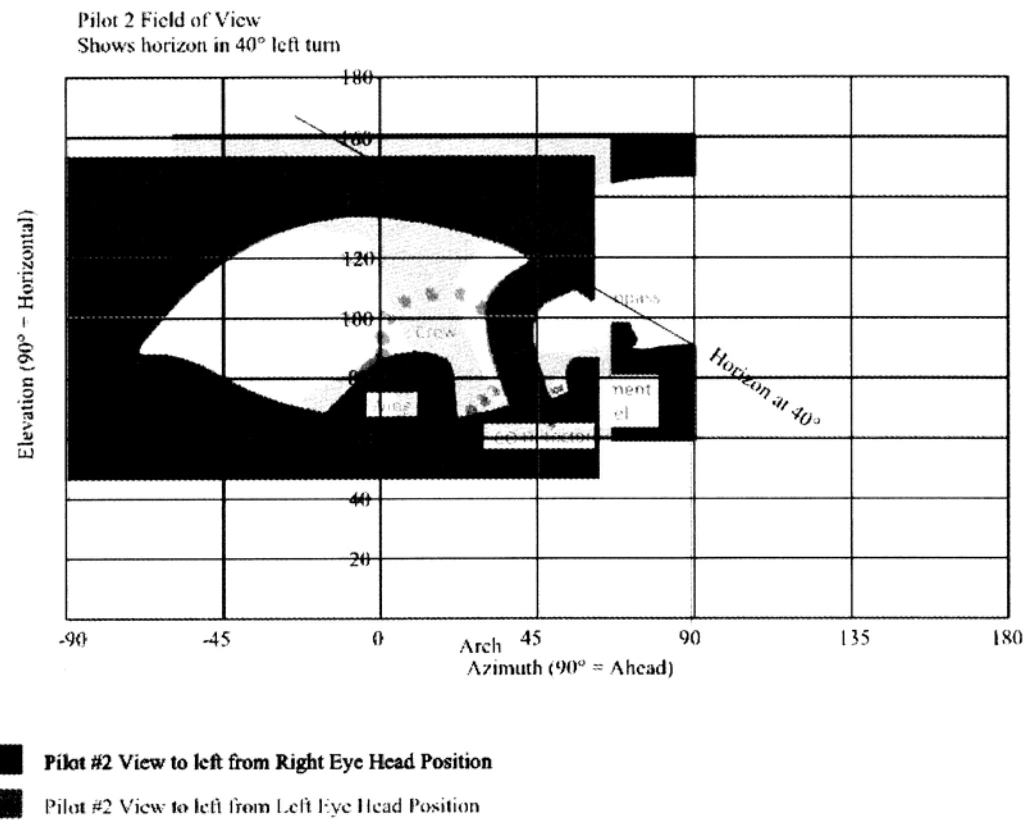


Figure 9. Obstruction to the FoV, showing a 40° AOB left turn (representing G-BYUT).

[25] Referenced on p9 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

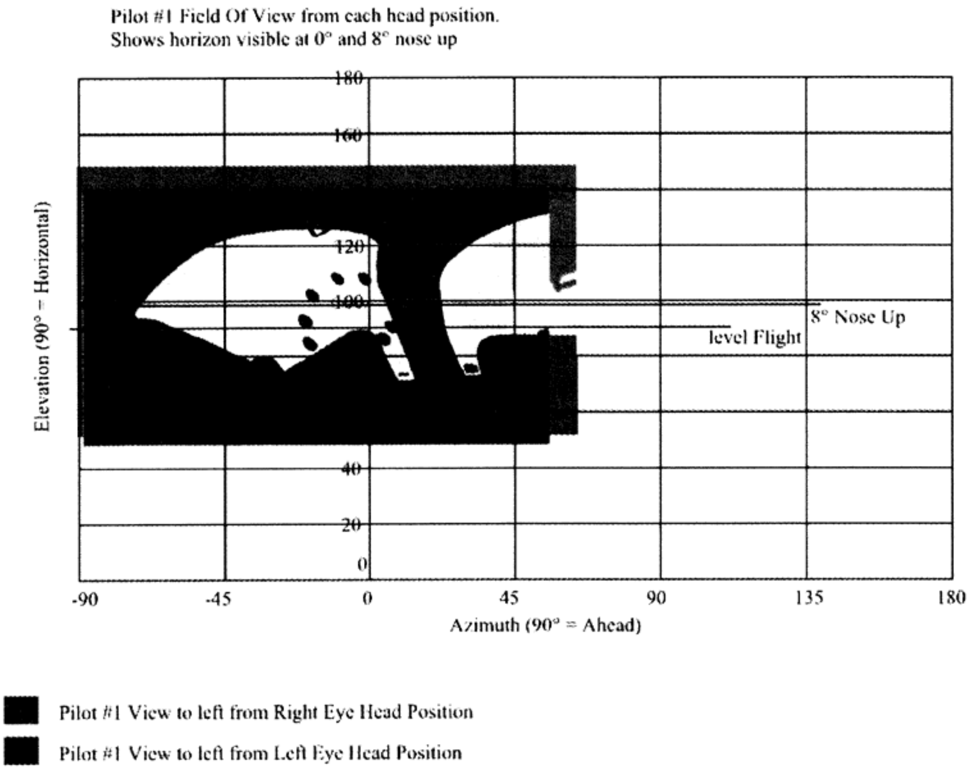


Figure 10. Obstruction to the FoV, showing varying climb angles (representing G-BYUT).

b. **Binocular and monocular Fields of View**. When sat in the primary (right hand) seat, the canopy arch to the right of a Tutor pilot obscures more of the outside field of view from any one seating position but is close enough for the pilot to be able to look completely around the obstruction. To the left, the Panel discovered that it is difficult to bring all of the area obscured by the left canopy arch into view despite moving the head and shoulders to the maximum comfortable extent when normally restrained. This is not readily apparent unless external reference points are employed; against an empty visual field, a pilot would be unable to establish whether or not he was fully clearing the blind area imposed by the Tutor aircraft canopy arch. Furthermore, the Panel discovered that most of the area that could be brought into view by moving the head and shoulders only became visible to one eye; this was not immediately apparent as the brain compensates for the blanked area and only by consciously closing one eye is the limitation apparent. When leaning forward, the area masked by the canopy arch to the left affects the left eye the most; the Panel members considered whether eye-dominance might be a factor in suppressing realisation of the extent of vision hidden to one eye but could find no research to support or erode such a theory. The Panel noted that eye-dominance is not recorded by RAF medical records.

c. **Windscreen zoning**. The Panel also noted that studies (White 1964)[26] have demonstrated that an observer looking for a target is less likely to scan areas of sky near to the edges of windscreens, as compared to areas further away from obstructions (Figure 11). It was not possible to determine if the lookout scans of the pilots of G-BYUT Annex AD

[26] Referenced on p10 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

and B-GYVN extended to the edges of the available FoV; windscreen zoning could not be discounted and was therefore a possible contributory factor.

Annex AN

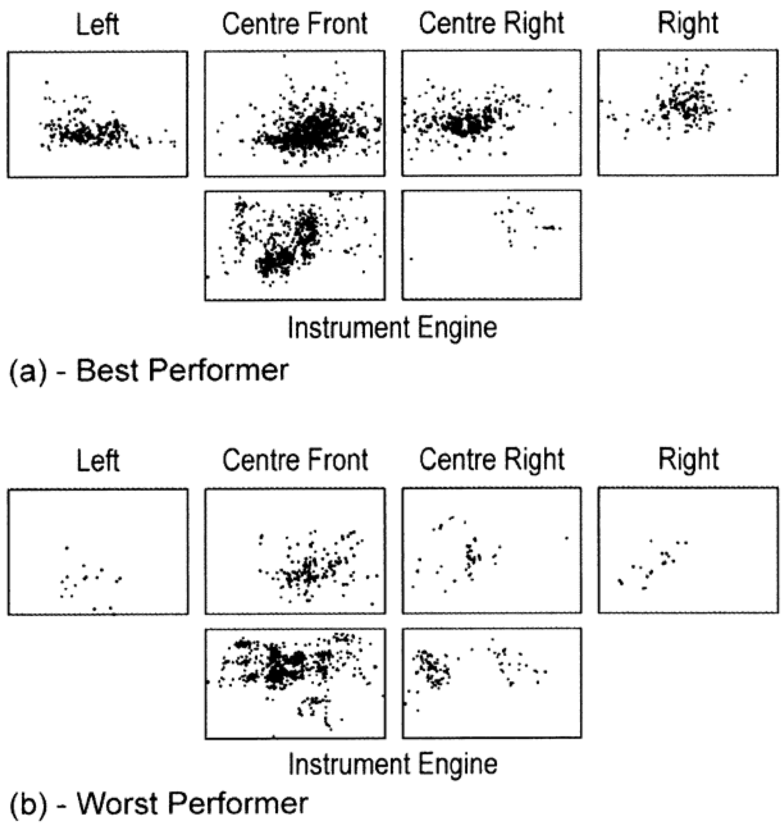


Figure 11. Results from a study of civilian pilots into 'windscreen zoning'; the dots indicate where the study pilots looked in the course of a simulator exercise, as determined by an eye-tracking device.

d. **Accident flight profile reconstruction**. To assess whether cockpit obscuration may have been a factor, the Panel arranged for a reconstruction of the flight profile. Panel members flew in the right hand seat to assess the visibility that would have been afforded to the pilots of G-BYUT and G-BYVN while handling pilots flew from the left hand seat and adhered to strict collision avoidance criteria, based principally upon altitude deconfliction. The Panel examined the radar trace data and, noting that the ARP makes it impossible to know precisely what heading, pitch and bank the aircraft had at any moment, designed a profile that followed an approximation of the major heading changes and the altitude returned by IFF Mode S. At the western extremity of the profile, the lead aircraft (representing G-BYUT) completed an aerobatic manoeuvre which radar trace returns and eye-witness accounts led the Panel to believe was a wing-over; as a relatively gentle manoeuvre, the Panel considered that this would have been consistent with a cadet's first flight. It was not possible to determine in which direction G-BYUT flew the manoeuvre on 11 Feb but the Panel did not consider that this detail had a significant effect upon the profile. For comparison, the radar trace data is depicted at Figure 12, followed by the simplified profile at Figure 13; radar trace returns from one of the reconstruction runs are also presented (Figure 14) to illustrate that the flight paths achieved were representative of the actual flight paths on 11 Feb, especially in the critical last seconds.

Annex AC

Annex AE

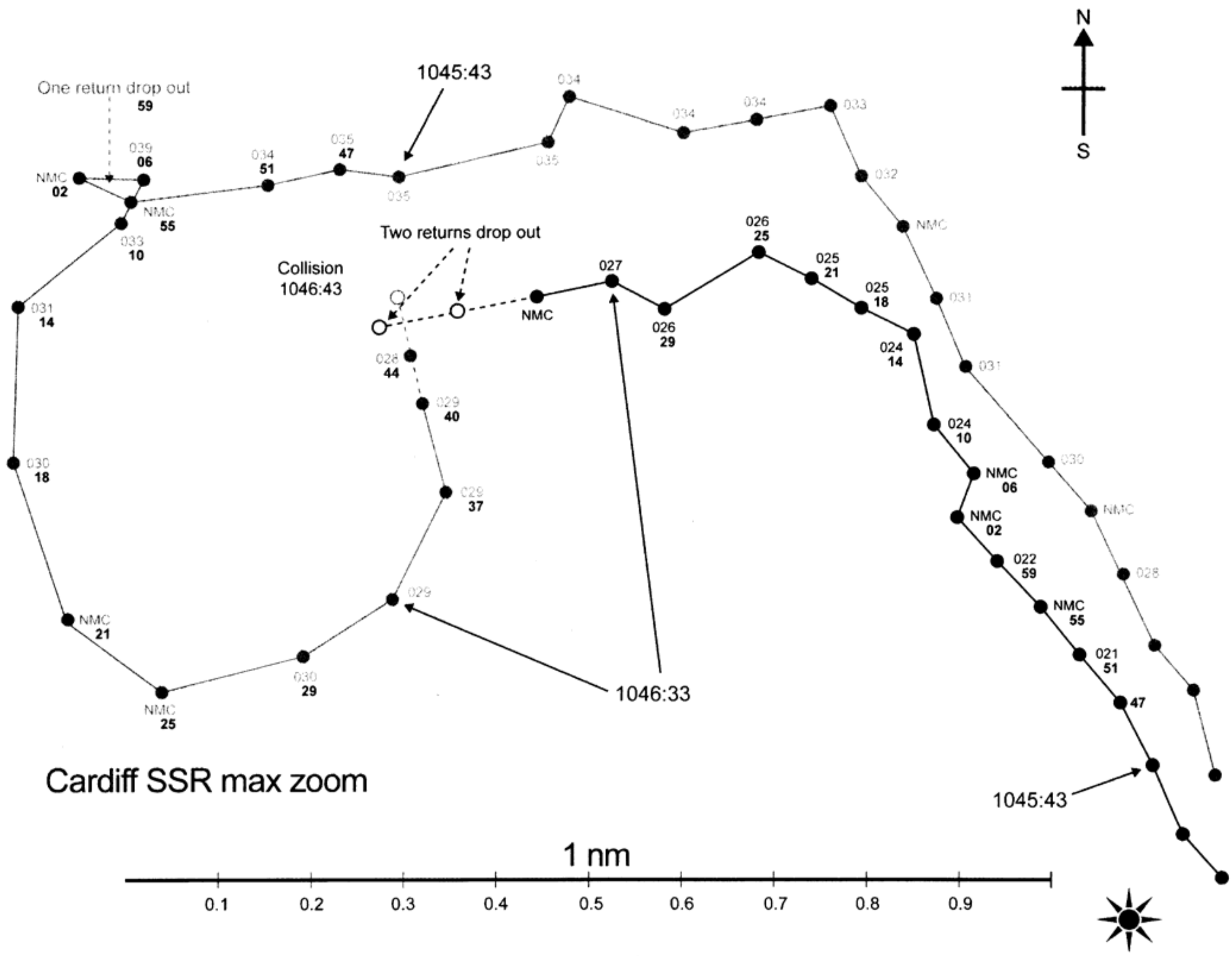


Figure 12. Graphic of Cardiff radar trace data (11 Feb 09).

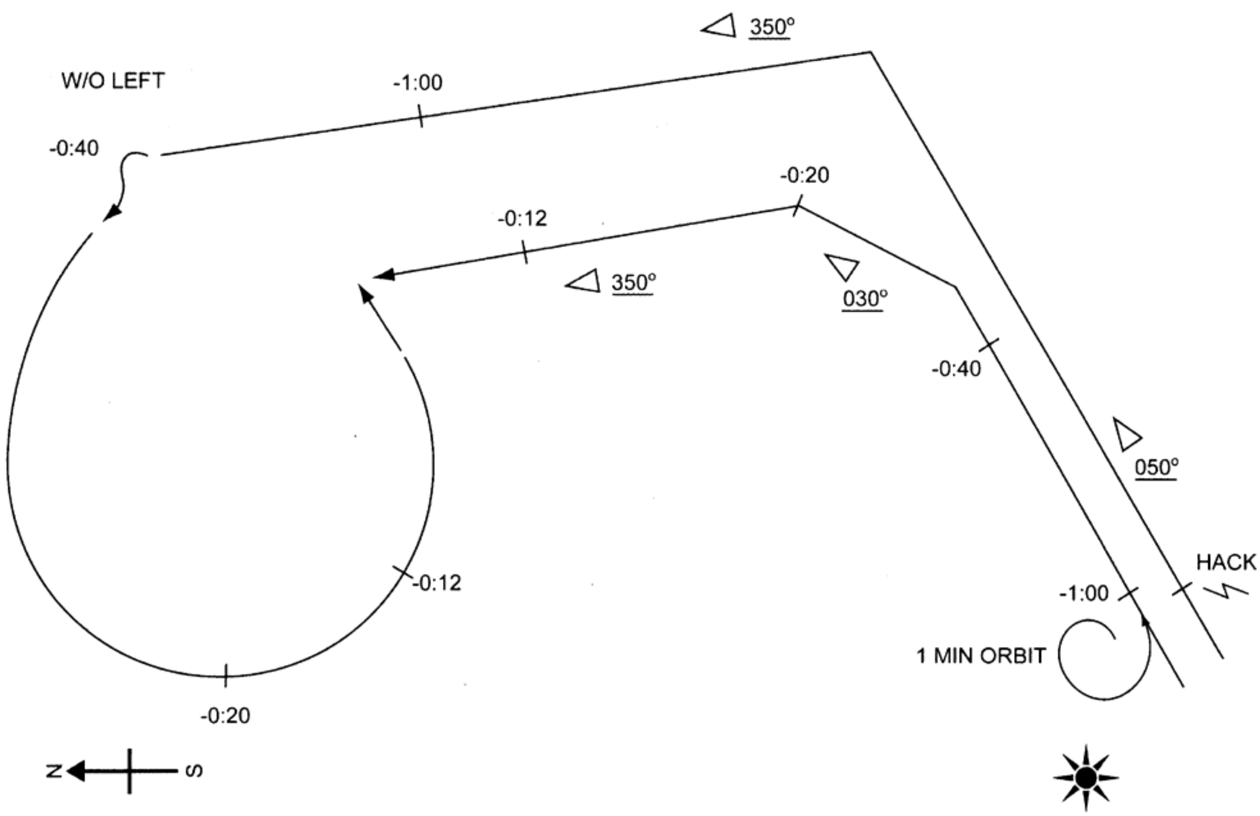


Figure 13. Graphic of reconstructed profile showing heading approximations and timing.

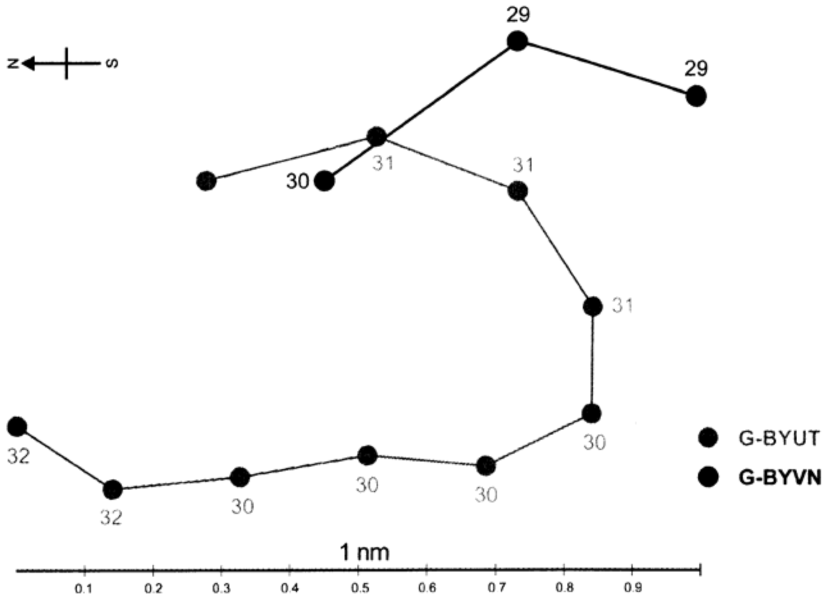


Figure 14. Graphic of radar trace from reconstruction flight. Figures represent altitude.

The accident flights were reconstructed twice: the first flight was flown in Lincolnshire on the afternoon of 25 Mar 09 and the headings were modified to put the sun (in the south west) into the same relative position to the aircraft as it would have been on the morning of 11 Feb 09 (in the south east); the second reconstruction of the accident sortie was conducted from MOD St Athan on 26 Mar 09 in the same general area as the accident flight and, though once again flown in the afternoon, an approximation of the headings flown on 11 Feb 09 was used, without catering for sun position. The results, though not definitive, provided compelling evidence that cockpit obscuration could have played a major part in preventing the pilots of both G-BYUT and G-BYVN from seeing each other as the point of collision was approached. For simplicity, the lead aircraft in the reconstruction flights is referred to as G-BYUT in the sub-paragraphs below, and the trail aircraft referred to as G-BYVN. The view from the right hand seat was recorded for each flight path and, as a result of the experience gained during the reconstruction flights, allied to assessment of the recorded video, the Panel noted that: Annex AC

i. Despite conditions of excellent visibility for both reconstruction flights, exceeding those prevailing on 11 Feb 09,[27] it was extremely difficult to retain visual contact with each aircraft at the separation that equated to a 1 min trail. Specifically, the tail aspect of G-BYUT, as seen from G-BYVN while in trail, was extremely difficult to detect (Figure 15) and the pilots in the following aircraft were unable to keep a constant 'padlock'[28] despite devoting increased attention to the task and knowing where to look. This task was most difficult when G-BYUT was viewed against a background of cloud, resulting in very little contrast. On 11 Feb 09 the SW Police ASU video reveals that extensive cloud was present to the north west of the area of collision and would have been the most likely Annex Q

[27] Actual weather (Cranwell METAR 1550Z 25 Mar 09) 290°/19 kts, visibility in excess of 10 km, cloud SCT 4000 ft amsl. MOD St Athan METAR 1600Z 26 Mar 09 280°/10 kts, visibility in excess of 10 km, cloud SCT 3000 ft amsl.
[28] 'Padlock' is a NATO brevity codeword to indicate maintaining visual contact with a target or point of interest.

background for G-BYUT along the line of sight from G-BYVN.

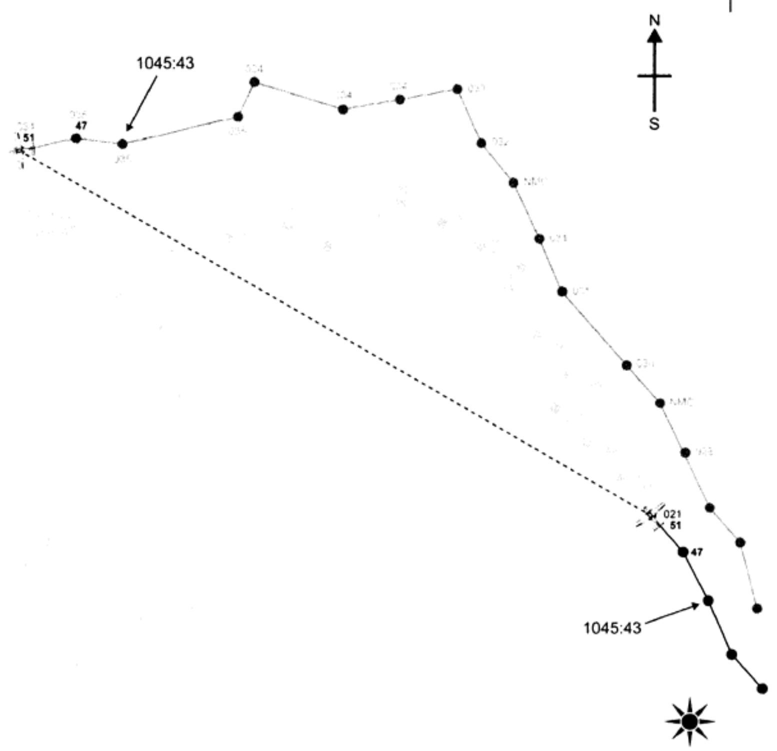


Figure 15. Relative disposition at 1045:51 showing that the pilot of G-BYVN would have been presented with a predominantly tail aspect of G-BYUT.

ii. The changing aspect of G-BYUT during the wingover would have created an increase in apparent size and increased relative motion, both of which, in isolation, might have increased the opportunity for visual detection. Unfortunately, this manoeuvre was possibly obscured by a combination of the canopy arch and canopy operating mechanism on G-BYVN (Figure 16).

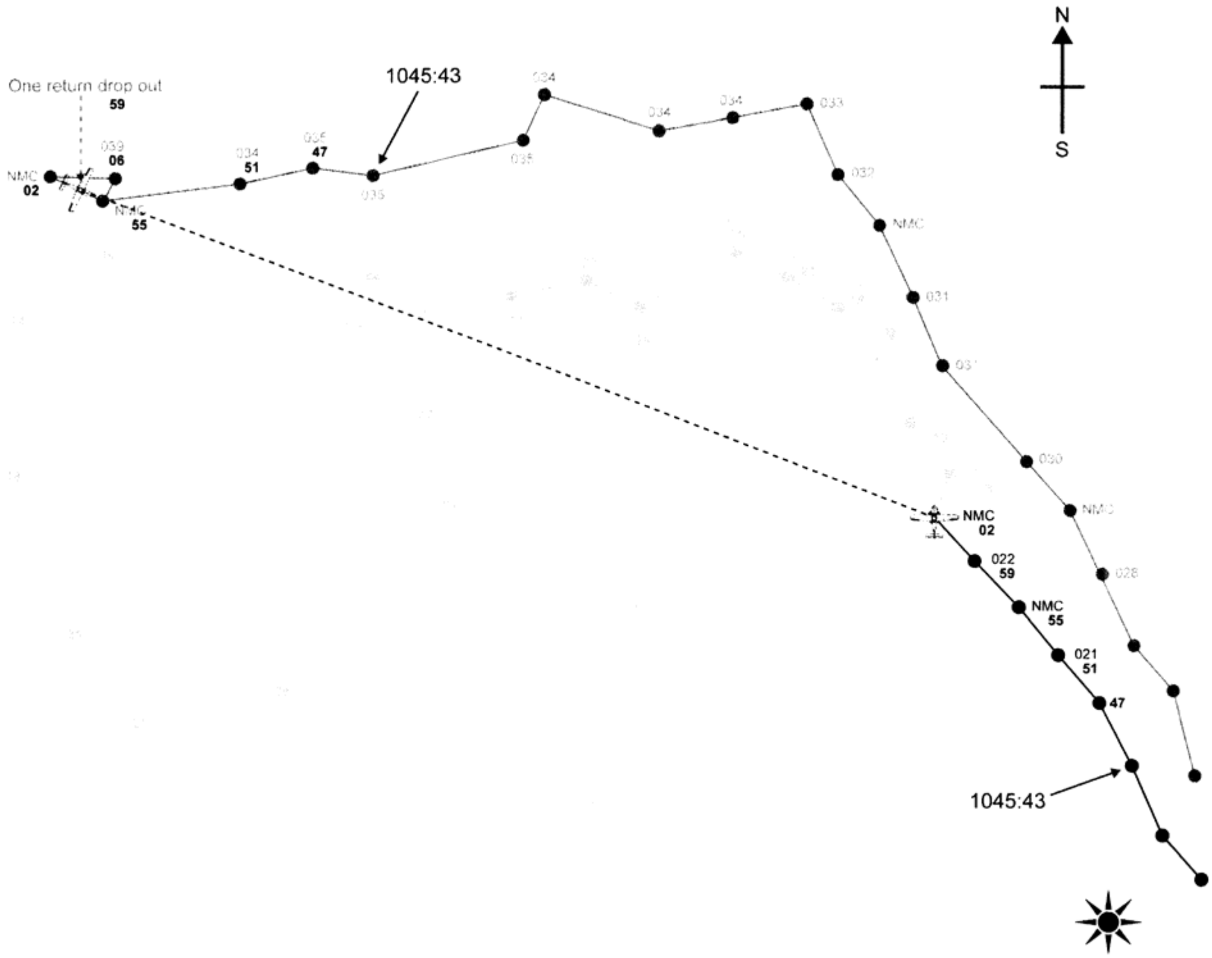


Figure 16. Relative disposition at around 1046:00 when G-BYUT is assessed to have executed an aerobatic manoeuvre. The left canopy arch of G-BYVN would have interrupted the line of sight for at least some of the time.

iii. In the reconstruction, as G-BYUT turned into the area of flight path conflict, and at the point where the pilot was most likely to have been looking towards G-BYVN as he looked into the turn (Figure 17), the angle of bank resulted in G-BYVN being obscured by the canopy and canopy operating mechanism and canopy spine (Figure 18).

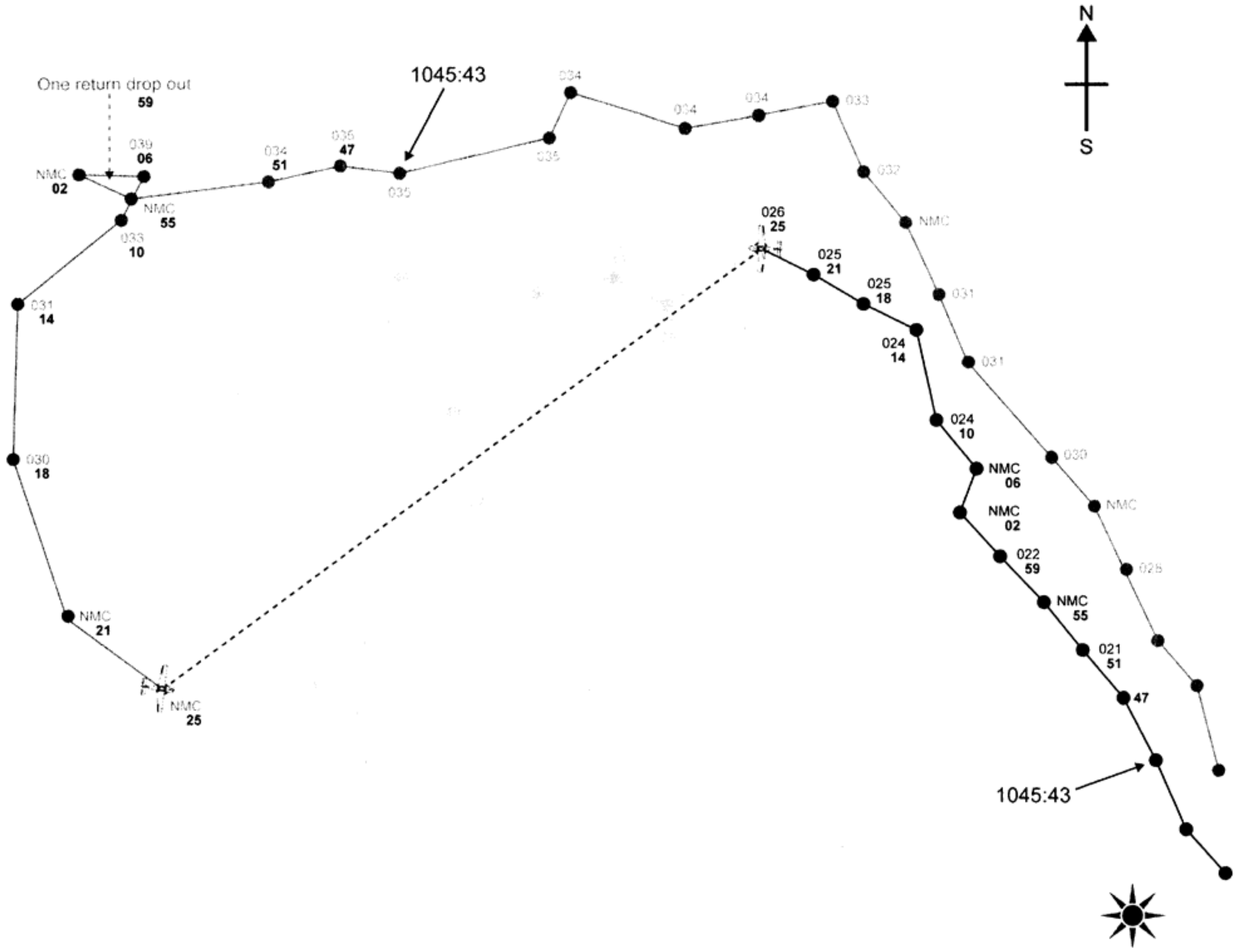


Figure 17. Relative disposition at 1046:25 when G-BYUT turned into the area into which G-BYVN was heading.

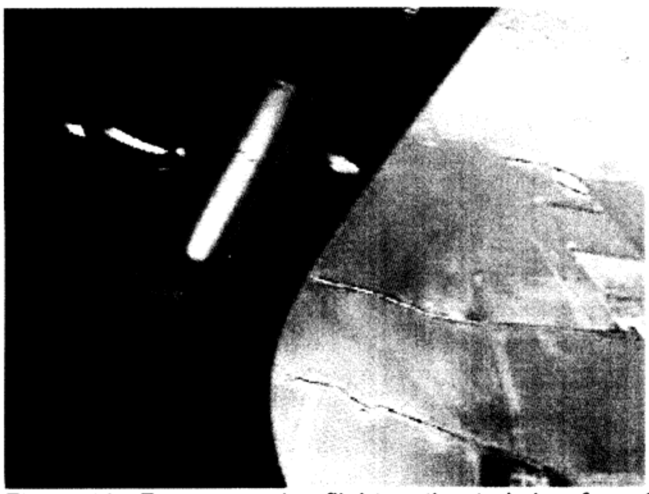


Figure 18. Reconstruction flight: estimated view from G-BYUT at 1046:25 looking towards G-BYVN, 25 secs prior to the simulated collision point.

iv. As G-BYUT continued the turn, its nose came through G-BYVN which transitioned across G-BYUT's windscreen and was unobstructed for about 15 secs (Figures 19 and 20).

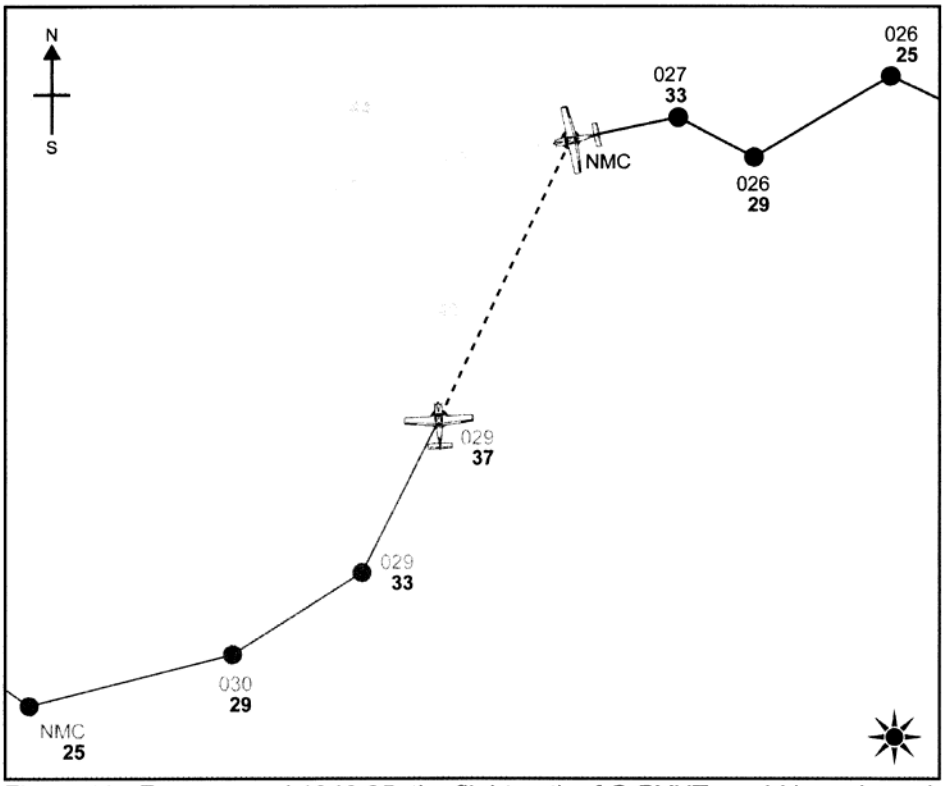


Figure 19. From around 1046:25, the flight path of G-BYUT would have brought its nose through G-BYVN.


Figure 20. Reconstruction flight: Tutor simulating G-BYVN circled, approximately 7 secs prior to the simulated collision point.

Of this period of time, the relative movement was highest at the greatest range, with G-BYVN moving from the canopy handle area to the low, right extremity of the windscreen in about 14 secs, equating to a range (from the radar trace) of about 0.8 nm decreasing to about 0.3 nm. At 0.3 nm, G-BYVN (approximately beam aspect) would subtend an angle of 0.77° at the eye of G-BYUT's pilot which is roughly equivalent to an object 13 mm wide at a viewing distance of 1 m. For most of the remaining 10 secs leading up to the collision, G-BYVN would have remained in approximately the same low, right position in the windscreen, possibly being obscured under the nose (Figure 21) for the last 2 or 3 secs before collision, the period of time when the apparent growth in size of G-BYVN would have been greatest.

Figure 21. Reconstruction flight: Tutor simulating G-BYVN circled, approximately 3 secs prior to the simulated collision point.

v. There was no way to determine positively where the pilot of G-BYUT was looking in the last 20 secs prior to collision but the Panel agreed that the majority of his attention would most likely have been directed into the turn, clearing the projected flight path; this could have placed G-BYVN at or beyond the extremity of the Field of View of vision corrected by his Corrective Flying Spectacles. The Panel concluded that the ability to detect G-BYVN may have been compromised by a combination of obscuration by the frames of his Corrective Flying Spectacles and the reduced visual acuity resulting from the line of sight falling outside the area of corrected vision for much of the last 20 secs leading to collision. Corrective Flying Spectacles may therefore have been a possible contributory factor in the accident.

vi. The point at which obscuration may have occurred in the accident was difficult to determine accurately as the altitude deconfliction imposed to ensure safety during the reconstructed flights caused G-BYVN to be lower than would have been the case on 11 Feb, and thus the point at which G-BYVN would have disappeared under G-BYUT's nose would have occurred later in the turn, if at all. In assessing the video of this portion of the flight the Panel noted that G-BYVN was only conspicuous as a result of being presented against a background of terrain. It was apparent that if the background had been cloud, as was present a little above the flight path (see Figures 22 and 23) during the flight reconstruction, the lack of contrast would have made visual acquisition very difficult. On 11 Feb 09 the SW Police ASU video clearly shows that low cloud was present to the north east of the area of collision (Figure 24) and would have been the most likely background for G-BYVN. The Panel concluded that the white colour scheme of the Tutor, presenting little contrast with a bright background of cloud, was a probable contributory factor in the accident. Annex Q

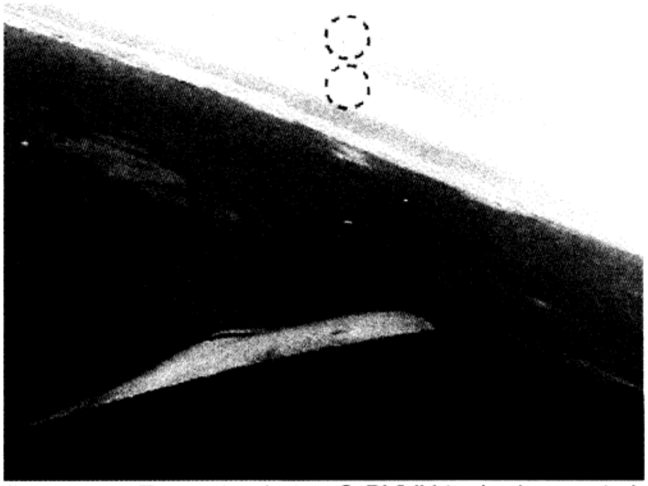


Figure 22. Tutor simulating G-BYVN in the lower circle, approximately 10 secs prior to the simulated collision point. Note the lack of contrast that would be apparent if the aircraft appeared against the sky or cloud in the circles above.

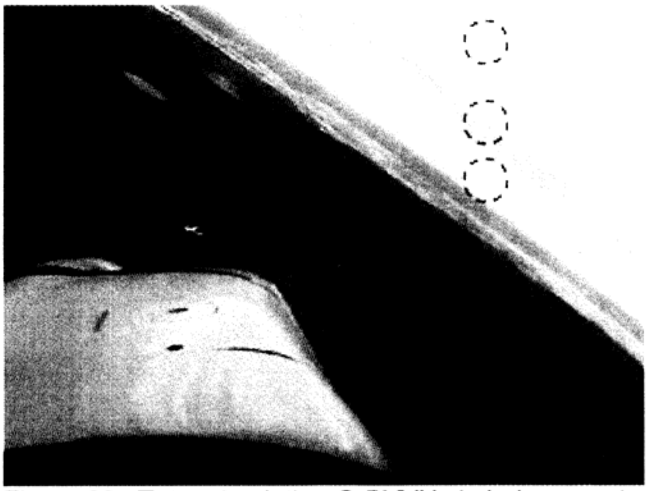


Figure 23. Tutor simulating G-BYVN circled, approximately 4 secs prior to the simulated collision point. Note the lack of contrast that would be apparent if the aircraft appeared against sky or cloud, as in the circles above and right. Note too the elevated camera position to achieve an unobstructed view over the nose of the aircraft.

Figure 24. Photo taken by SW Police ASU on 11 Feb 09, shortly after the crash, looking east from a position that demonstrates the approximate view presented to the pilot of G-BYUT about 20 secs before the collision. The burning wreckage of G-BYVN can be seen on the right. Note the backdrop of cloud on the horizon.

vii. Within the cockpit of G-BYVN, the heading changes conspire to keep G-BYUT almost completely masked, initially by the canopy arch (Figure 25) and latterly by the area that would have been hidden from view by the adjacent cadet. Although the cadet in G-BYVN was smaller than the handling pilot during the reconstructed profile, the altitude safety separation resulted in G-BYUT occupying a point higher in the canopy during the final closure (Figure 26) than it would have done on 11 Feb 09, remembering that G-BYUT struck G-BYVN below the wing line. The Panel concluded that the pilot of G-BYVN would have had difficulty observing the final approach of G-BYUT as a result of interruption of the sight line by the canopy arch and the adjacent cadet; obscuration was therefore very likely to have been a contributory factor.

Figure 25. Reconstruction flight: estimated view from G-BYVN of Tutor simulating G-BYUT (circled) approximately 4 secs prior to the simulated collision point. The sun is obscured by cloud.

Figure 26. Reconstruction flight: estimated view from G-BYVN of Tutor simulating G-BYUT approximately 1 sec prior to the simulated collision point. Note the elevated camera to achieve an unobstructed view over the adjacent seat occupant. In the reconstruction, height separation was maintained.

viii. The precise orientation of the sun in the final seconds cannot be determined because it is dependant upon aircraft heading, which cannot be known precisely due to the ARP of the radar. Nevertheless, the reconstruction flight was orientated to put the sun in the same general area, based upon the flight path trend recorded, and timed to put the sun at 20.6° above the horizon which accurately replicated the conditions at 1046Z on 11 Feb 09. It was apparent that G-BYUT would have approached G-BYVN from the general direction of the sun (Figure 27) and the Panel concluded that glare would have made visual detection even less likely and was therefore a possible contributory factor. Annex AB

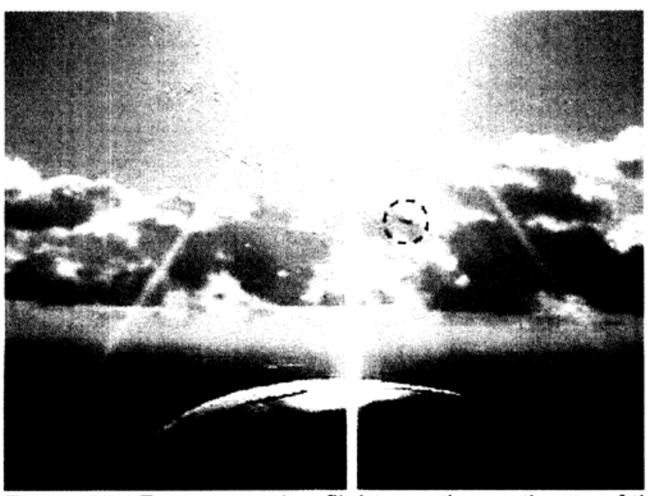


Figure 27. Reconstruction flight: another estimate of the view from G-BYVN of Tutor simulating G-BYUT approximately 1 sec prior to the simulated collision point. Note the alignment of the line of approach with the sun.

38. **Conclusions derived from the accident profile reconstruction**. The Panel determined that the final flight paths leading to collision placed G-BYVN in the low, right windscreen of G-BYUT for at least 20 secs, with a background of bright cloud. If the pilot of G-BYUT was looking into the turn, as could reasonably be expected, then G-BYVN is likely to have been obscured by the frames of his Corrective Flying Spectacles or outside the area of corrected vision. In the final few seconds before collision, when apparent growth would be greatest, G-BYVN is likely to have been obscured by the nose of G-BYUT. The pilot of G-BYVN was likely to have had his view of G-BYUT interrupted by a combination of the left canopy arch and the adjacent cadet, and had to contend with glare from the sun. For both pilots, the opposing aircraft would, if not entirely obscured, have approached from close to a limit to the available FoV; although determined from a survey of civilian pilots conducting a simulator based exercise, the Panel noted the findings of studies that suggest that lookout scans tend to neglect the edges of the available FoV. An appreciation of the final angle of arrival of each aircraft, as seen from the pilots of G-BYUT and G-BYVN, is provided in Figures 28 and 29.

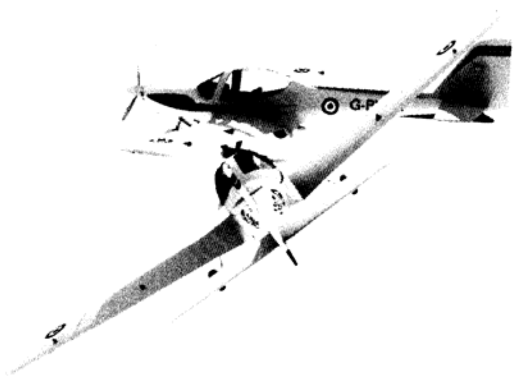


Figure 28. Estimated sightline of G-BYUT.

Figure 29. Estimated sightline of G-BYVN.

The Tutor is fitted with a fixed harness restraint system which prevents significant movement of the pilot fore and aft; the inclusion of a 'go forward' mechanism would allow the pilot to increase his range of in-cockpit movement to look around obstructions to the line of sight. The Panel concluded that cockpit obscuration, in particular the width of the Tutor canopy arch, the presence and size of the canopy spine and handle, and the lack of a 'go-forward' lever, were contributory factors in the accident; Tutor conspicuity was a probable factor and windscreen zoning, the FoV limitations and reduced visual acuity imposed by Corrective Flying Spectacles, and glare from the sun were possible contributory factors.

39. **Cockpit workload and in-cockpit distractions**. There is an enduring and inescapable requirement to look inside the cockpit of all current aircraft to attend to essential tasks such as interpreting maps or navigation aids, checking flight parameters, monitoring engine performance and remaining aware of fuel consumption. While performing such checks it is not possible to direct the human binocular vision elsewhere or to focus upon distant objects. In-cockpit tasks must therefore be performed in short intervals within a workload cycle that devotes the majority of time and attention to searching for conflicting traffic. The temptation to dwell upon tasks in-cockpit can be very powerful when the number of tasks increases or the time available to complete them is short but this interruption to a good lookout scan must be resisted and

is repeatedly emphasised during RAF flying training.

a. **Distraction**. The Panel considered the possibility that an event or incident resulted in an in-cockpit distraction to the pilots of either aircraft but could find no evidence to support such a notion. Neither aircraft appeared to be in distress prior to the collision and there was no evidence in the wreckage of either aircraft to suggest a failure or emergency indication. Furthermore, the Panel considered that an in-cockpit problem would more likely lead to a pilot selecting straight and level flight or commencing a turn towards base, neither of which was apparent. Although it was the first flight for each cadet and they exhibited a normal level of apprehension, they nevertheless appeared to be looking forward to their flights and were not unduly nervous. The Panel therefore considered it unlikely that they became sufficiently distressed to create a distraction; both cadets' sick bags were still stowed within their respective flying suit pockets and the Panel therefore also considered it unlikely that either cadet was being sick, which would have similarly presented an in-cockpit distraction prior to the collision. Overall, the Panel considered that distraction could not be discounted as a factor in the accident but was unlikely. Annex M

b. **Visual field narrowing**. Studies (Leibowitz 1973, Baddeley 1972, Mackworth 1965)[29] have demonstrated that an observer's functional field of vision can vary significantly from one circumstance to another and that the imposition of a moderate workload, fatigue or stress will induce a narrowing of the visual field or 'tunnel vision'. The Panel considered that the cockpit workload within each aircraft would have been low, comfortably within the capacity of each pilot and that narrowing of the visual field was therefore unlikely to have been a factor. Annex AD

40. **Expectation**. If the pilots of either G-BYUT or G-BYVN developed a Mental Air Picture that the other aircraft had manoeuvred to a particular area then they may have concentrated their lookout in the wrong area. Although no radio calls appear to have been made between the aircraft and the Panel found no evidence of established patterns of behaviour that might have led either pilot to assume that the other had routed to a particular area, the Panel noted that if the pilot of G-BYVN had achieved brief visual contact as G-BYUT completed its wing over then it would have appeared to be heading south-west and away from the area into which G-BYVN was flying. This may have led the pilot of G-BYVN to concentrate any subsequent attempts to regain visual contact in the wrong area. Nevertheless, the Panel considered that both pilots were thoroughly trained to be aware of the threat posed by more than one aircraft and that fixation on any one contact was detrimental to good lookout. Overall, the Panel could not discount that a misplaced Mental Air Picture as a result of 'expectation' may have led either pilot to concentrate his lookout in the wrong area but that this was unlikely as a factor in the accident. Annex AE

Human Factors affecting the ability to 'Avoid'

41. **Response time**. A number of studies (FAA advisory circular 90-48-C) have assessed the time required to execute a successful evasive manoeuvre. The calculations do not include search times but assume that the target has been detected. Thereafter, the total time required to recognise an approaching Annex AO

[29] Referenced on p13 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.

aircraft, recognise a collision course, decide upon action, execute the control movement and allow the aircraft to respond is estimated to be between 5 and 12.5 secs (Figure 30). Therefore to have a good chance of avoiding a collision, a conflicting aircraft must be detected about 12.5 secs prior to the time of impact. Response times will vary with circumstance and between individuals.

Time to react to collision threat from FAA advisory circular

Annex AD

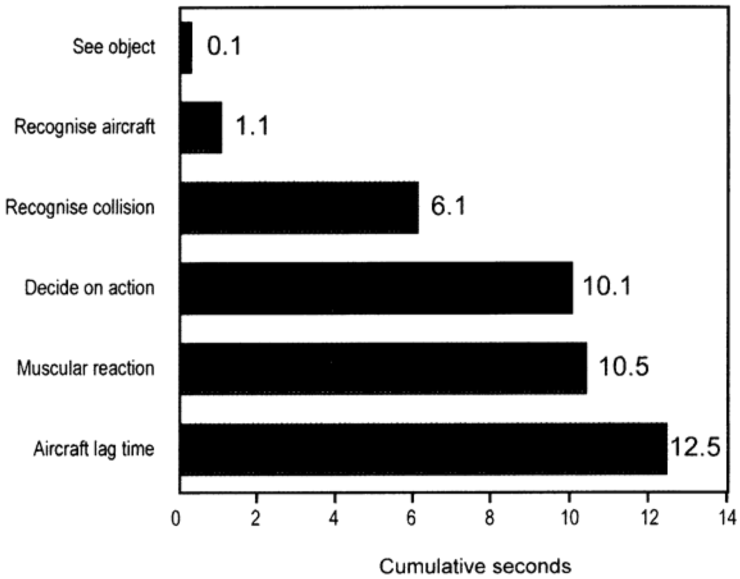


Figure 30. Reaction times to evade a collision threat.

42. **Threat recognition**. Following the wing-over, G-BYUT would only have presented a possible flight path conflict when it commenced its turn to the left. The potential for conflict would not have been readily apparent until the aircraft were on approximately reciprocal headings (Figure 31), with only about 18 secs to collision, and then only if the turn was continued; if G-BYUT had rolled out of its turn at any stage up until about 3 secs to go to collision then it would have passed astern of G-BYVN and separation would have been maintained.

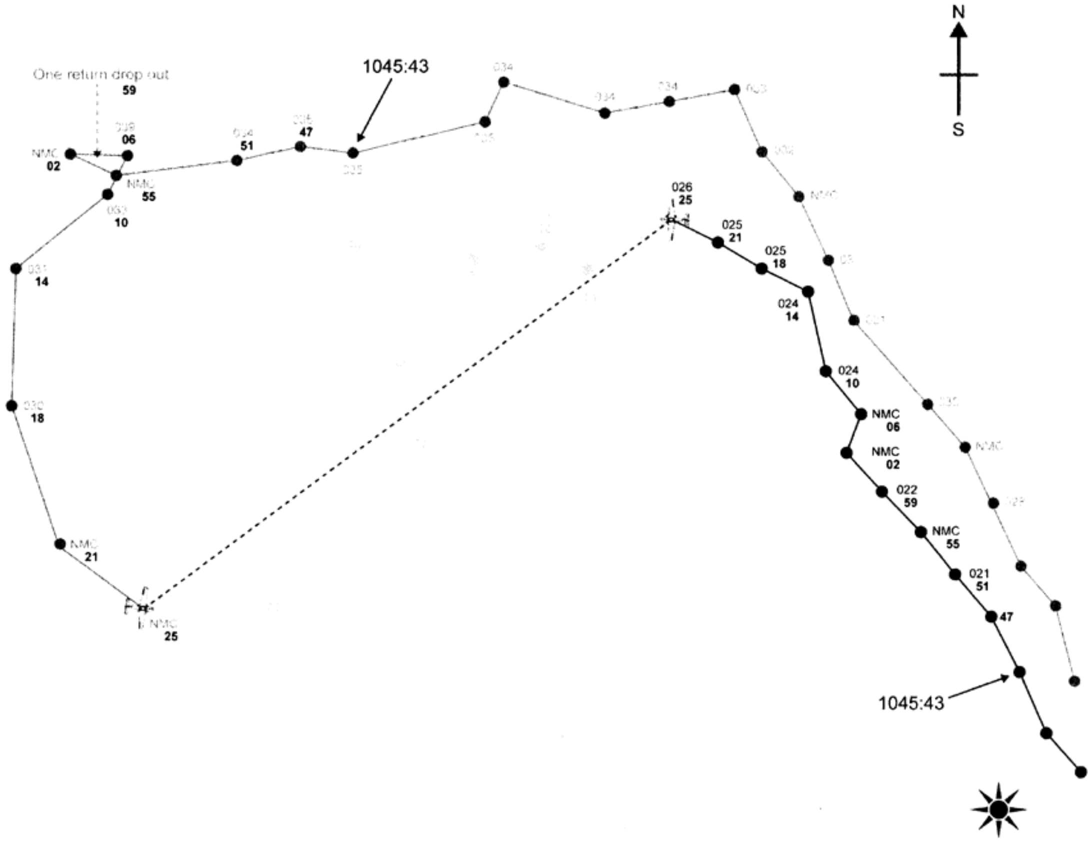


Figure 31. The flight path conflict only arises after 1046:25 and, even if the pilot of G-BYVN was visual, the threat may not have been apparent until around 1046:33, only 10 secs prior to the collision.

43. **Collision avoidance manoeuvre**. The Panel considered that the pilot of G-BYUT would not have continued his turn if he had gained sight of G-BYVN at any stage. Conversely, G-BYUT would not have presented an obvious threat to the pilot of G-BYVN until quite late, possibly as little as 10-14 secs to go until collision. The Panel could not discount that the pilot of G-BYVN was visual with G-BYUT but that he did not recognise the threat and execute an effective evasive manoeuvre in the time available.

a. **Assumption**. If the pilot of G-BYVN was visual with G-BYUT as it turned towards him, he may have initially assumed that the pilot of G-BYUT was visual with him and flying a deliberate profile, especially given the greater experience of the pilot of G-BYUT. Although the Panel considered it unlikely that the pilot of G-BYVN would have allowed an unsafe situation to develop without taking action, any initial doubt or assumption with regard to the intentions of G-BYUT would have consumed valuable time available to determine and effect an evasive manoeuvre.

b. **Courses of Action available to G-BYVN**. The Panel noted that even if a flight path conflict was recognised, it would have been difficult to determine the optimum course of action; a turn away from G-BYUT would have made it more difficult to maintain visual contact and would therefore be an unlikely option to select; a turn towards could exacerbate the flight path conflict, especially if the pilot of G-BYVN expected that G-BYUT might roll out, and would very quickly have ceased to be a viable course of action as the requisite turn exceeded the aerodynamic capability of the Tutor aircraft; G-BYVN did not have sufficient speed to zoom climb appreciably; and a bunt would be an uncomfortable and unnatural manoeuvre, especially as G-BYUT was descending and was destined to impact below the cockpit area of G-BYVN.

Only one witness described any pre-collision manoeuvre, with all other witnesses describing no last second changes to the established flight paths. Nevertheless, one witness described a pull-up by G-BYVN 'as if entering a loop' and it is possible that this might not have been readily apparent to other points of observation, especially those that were closer and thus observing more of a plan form aspect of the collision. The orientation of G-BYUT and G-BYVN as determined by the collision damage is relative only to each other and not external references; thus the Panel could not discount the prospect that the pilot of G-BYVN saw G-BYUT and attempted to pull up and over the flight path of G-BYUT. However, most evidence indicated that the aircraft were in steady flight prior to the collision and therefore, on balance, the Panel assessed that neither pilot saw the other aircraft in time to change the aircraft flight paths. Witness 27

Studies to assess the effectiveness of 'See and Avoid'

44. The Panel noted that 4 RAF studies relating to See and Avoid were conducted between 1991 and 1993 but that little analysis (a study in 2002 assessed training helicopter conspicuity) had been conducted in the intervening period despite the emergence of electronic aids to conspicuity. Annex AL

45. A DERA study (April 1997) used a computer simulation of activity in the UK Low Flying System (UKLFS) to predict rates of confliction which were then validated against reported confliction rates (from the Joint Airprox Working Group) and the historical record of collisions. The report concluded that See and Avoid is more than 99% effective and tied its validity to the accuracy of its predictions (one FJ–FJ collision every two years and one military–civilian collision every six years) which have continued to prove tragically accurate. Nevertheless, the study is based upon computer modelling only and did not include any live trials of pilot performance. Although aircraft size, reflectance, lights and environmental conditions were modelled, the report does not make any allowance for lookout technique, assumes that the pilot is maintaining a constant scan without interruption or distraction and does not cater for obstructions to the field of view. The Panel, with support from the current RAFCAM HF specialist, does not support a conclusion that See and Avoid is 99% accurate; even in the unlikely event that pilots could consistently scan the entire visual field, without obstruction and within the time taken for an opposing aircraft to close from being imperceptible to within a range that exceeds pilots' reaction time, for more than 99% of the time airborne, human visual system limitations could still prevent the conflicting traffic from being detected. The Panel concluded that the accuracy of the DERA predictions owes more to the probability of conflicting flight paths arising than the likelihood of a pilot subsequently resolving the conflict.

46. A number of international studies, summarised at Annex AQ, have addressed the overall issue of risk of collision and the effectiveness of the See and Avoid principle. All acknowledged the underlying physiological limitations at play and that, when mid-air collisions occur, 'failure to see-and-avoid is due almost entirely to the failure to see[30].' Field trials in the US (Andrews, 1977, 1984 and 1987)[31] with 24 General Aviation pilots who were intercepted during Annex AQ Annex AD Annex AD

[30] Referenced on p13 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.
[31] On p3 of the above report. Original reference not sourced.

low workload portions of assessed flights resulted in just 36 sightings among 64 encounters – or 56%.

Improving the safety of VFR operations.

47. **Collision probability**. One of the factors which determine the probability of a collision is the number of possible collision combinations in a particular airspace. The number of possible collision pairs is given by the formula: P = N x (N-l)/2 where N is the number of aircraft operating in a given airspace. For example, with only 2 aircraft there is only one possible collision pair, with 5 aircraft there are 10 possible pairs and with 10 aircraft there are 45. Measures to reduce local traffic density, even slightly, will therefore have a disproportionately greater effect at reducing the likelihood of a collision. Annex AD

48. **See and Avoid limitations**. The Panel concluded that the process of searching for other aircraft within the available visual field for the purpose of resolving conflicts with other traffic is an uncertain method of deconfliction. The process takes valuable time, must compete with other cockpit tasks, is affected by aircraft conspicuity and meteorological conditions, and is often compromised by blind spots created by obstructions to the field of view. Furthermore, well-documented Human Factors can reduce the chance that a threat aircraft will be seen and successfully evaded. These Human Factors are neither 'errors' nor signs of 'poor airmanship', they are limitations of the human visual and information processing system which are present to various degrees in all pilots.

49. **Enhancing deconfliction**. There is insufficient suitable UK airspace available to separate all RAF flights by distance, altitude or time and this would not cater for uncoordinated traffic or the inevitable effect of weather, which would serve to compromise the suitability of pre-assigned areas for sortie aims. The Panel recognises therefore that complete segregation of traffic is neither practical nor possible given the limitations of ATC capacity and coverage. Deconfliction based upon See and Avoid will therefore continue to have a place in RAF flying for the foreseeable future, not least due to the flexibility of operations that VFR permit. Nevertheless, the inherent risk of operating under VFR, while small, must be recognised and judged to be commensurate with the mission or training aims. Overall, the probability of a mid-air collision owes more to the probability that flight paths will intersect in time and space than upon the likelihood that the conflict will be resolved by successful application of the See and Avoid principle; the most effective response to the many limitations of See and Avoid is to minimise reliance upon it. All measures to reduce traffic density will enhance the effectiveness of deconfliction that is based upon See and Avoid. Where additional measures to enhance Situational Awareness (such as use of the radio) or increase separation assurance (by using an ATC service for example) are available and practical then they should be exploited.

50. **Alerted search**. In the absence of frequently sighting traffic, where detection would provide a positive feedback loop, scanning becomes a vigilance task, and humans are well known to be generally poor at maintaining vigilance beyond short periods or monitoring for events that rarely occur (Baker, 1960; Smith, 1969)[32]. Training and discipline can compensate to a degree but as lookout must compete with other cockpit tasks for limited cognitive resources, the absence of feedback or additional stimulus is likely to Annex AN

[32] Referenced on p1 of the Study 'Is Pilots' Visual Scanning Adequate to Avoid Mid-Air Collisions?' by Colvin, Dodhia and Dismukes. The Panel did not source the original reference

cause lookout to deteriorate over time. Traffic information prompts a pilot to search for a known or suspected aircraft and lookout is therefore less likely to be a fruitless search, especially where the scan is directed into a defined area. Overall, a traffic search in the absence of traffic information is less likely to be successful than a search where traffic information has been provided because knowing where to look, or even when to look, greatly increases the chance of sighting the traffic (Edwards and Harris 1972)[33]. Field trials conducted by John Andrews (Andrews 1977, Andrews 1984, Andrews 1987)[34] found that: Annex AD Annex AD

a. In the absence of a traffic alert, the probability of a pilot sighting a threat aircraft is generally low until a short time before impact. Annex AD

b. Traffic alerts increase search effectiveness by a factor of 8. A traffic alert from a collision warning system, ATS or from a radio listening watch is likely to be similarly effective. Annex AD

51. **Electronic conspicuity**. In-cockpit collision warning systems and portable traffic alert systems, which improve electronic conspicuity and alert the pilot to the presence of other transponding aircraft, are universally regarded as providing a far greater degree of protection than visual lookout alone can afford. Displays of altitude difference, trend and direction (if available) provide a prompt that traffic is nearby and provide the pilot with additional information to avoid a collision. As a collision can only occur at the altitude of the conflicting aircraft, flight path conflicts can be resolved in the vertical even if visual contact cannot be achieved. Although only effective against transponding aircraft, collision warning systems combine flexibility with enhanced Situational Awareness and an increased chance of detecting traffic that may present a threat. Collision warning systems could make the single greatest contribution to avoiding aerial collisions and the Panel concluded that the lack of a collision warning system on the Tutor was a contributory factor.

Lookout techniques

52. Despite the many limitations of See and Avoid, visual lookout will always present the last line of defence and it should not therefore be dismissed. For lookout to be effective, the field of view must be searched systematically in a manner that takes account of the limitations of the human visual system and the areas of obscuration specific to the type being flown. Individual eye movements associated with visual search take a small but significant amount of time. At most, the eyes can make about three fixations per second (White 1964)[35] but when scanning a complex scene pilots will typically spend more time on each fixation and the FAA estimates that around one second is required at each fixation. Without training to ensure that a systematic search is conducted, large areas of the field of view are likely to remain unsearched. The FAA recommends (FAA Advisory Circular 90-48 C) scanning the entire visual field outside the cockpit with eye movements of 10° or less to ensure detection of conflicting traffic; to scan an area 180°horizontal and 30° vertical could therefore take 54 fixations at one second each = 54 secs. Not only is this an impracticable task but the scene would have changed before the scan was finished. Annex AO Annex AP

53. **Current RAF lookout scan pattern**. The Panel could find no evidence that the recommended lookout pattern taught during flying training

[33] Referenced on p12 of the ATSB report 'Limitations of the See-an-Avoid Principle' dated Apr 1991. The Panel did not source the original reference.
[34] Also on p12 of the ATSB report. Original reference not sourced.
[35] On p9 of the ATSB report. Original reference not sourced.

had been developed or refined as a result of scientific analysis of the most effective technique to achieve a defined task. The Panel considered that the lookout technique taught during EFT might be improved if subjected to a fundamental review.

54. **The aim of lookout**. First and foremost, the aim should be established. Arguably, at the earliest stages of flying training, the sole objective should be to search for potential flight path conflicts in order to make each training sortie as safe as practicable. If agreed, then the lookout scan should be designed to detect the most likely threats. At any given time from a potential collision point, aircraft will be a displaced by a distance that is dependant upon their groundspeed. It can be seen from Figure 32 that in the case of a slow moving aircraft like the Tutor that a faster threat aircraft can approach the impending collision point from any direction relative to the Tutor; this serves to support a lookout scan that encompasses as much of a full 360° as possible, as described in the Tutor Training Manual.

When converging upon an impact point at different speeds,
the faster aircraft can appear from any direction

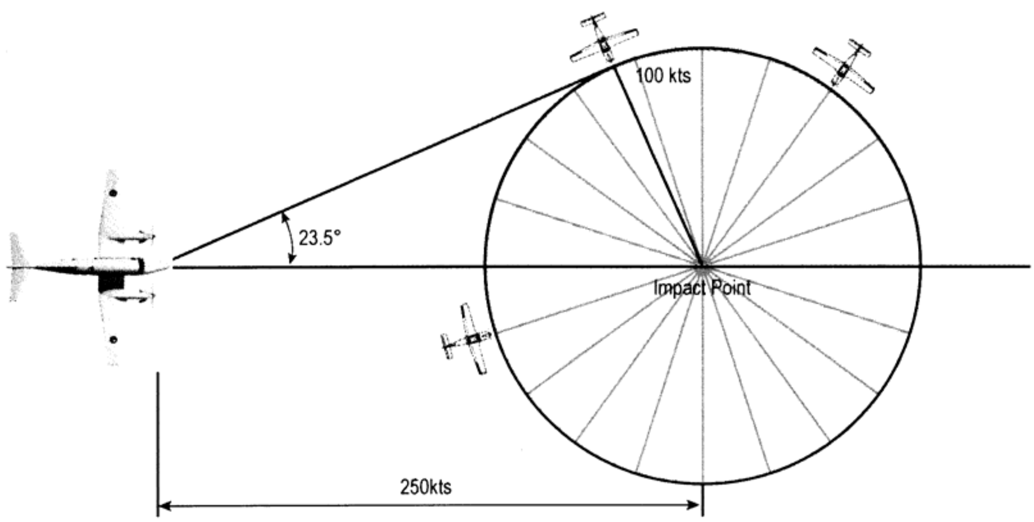


Figure 32. Relative orientation of aircraft closing to a collision point at different speeds.

Nevertheless, consideration of the other characteristics of faster aircraft is useful:

a. Although FJ aircraft transit the altitude band in which Tutors operate they are usually at very low-level (500 ft or less) or above 10 000 ft for economy of fuel. Furthermore, most RAF FJ aircraft have radar[36] to augment traffic detection, although serviceability and operating mode cannot be assumed. FJ aircraft may have 2 pairs of eyes searching (although this is of limited advantage given that slow moving aircraft will invariably appear ahead), may be flying in formation and thus benefit from mutual cross-cover, and will be more experienced and probably more current than student pilots[37]. Even if detected, a Tutor pilot will not have the aerodynamic capability to guarantee resolution of the potential conflict if the FJ pilot is not visual and adheres to a collision flight path.

[36] Only the Hawk and Harrier are not equipped with radar.
[37] A QFI or AEF pilot will be the aircraft captain for most Tutor and Firefly sorties but approximately 20% of the EFT syllabus is student solo.

b. More advanced training aircraft, such as Tucano and King Air, are fitted with TCAS.

c. Large Aircraft (including commercial aviation), like FJ aircraft, do not normally operate in the same altitude bracket as the Tutor. They also have the advantage of TCAS.

d. RAF Rotary Aircraft tend to operate in areas that are discreet from the normal operating airspace for AEF and EFT. Commercial helicopters also tend to operate in defined areas, will usually be equipped with TCAS and routinely use an ATS.

55. **Most likely threats**. The aircraft that RAF Tutors are most likely to encounter when operating at their normal altitudes are other training aircraft (Tutor and Firefly) and light General Aviation, to include light helicopters, gliders and microlights; these aircraft all have broadly similar, or slower, groundspeeds and it can be seen from Figure 33 that aircraft converging on a constant heading, at similar groundspeeds, will appear no further aft than the 3/9 line[38] of the opposing aircraft.

When converging upon an impact point at similar speeds, the conflicting traffic will appear ahead of the 3/9 line.

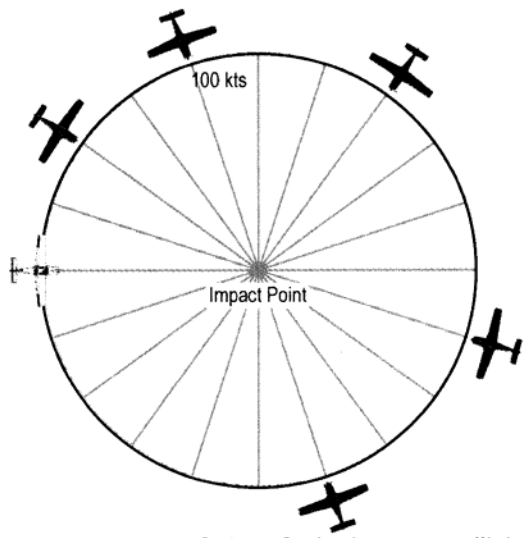
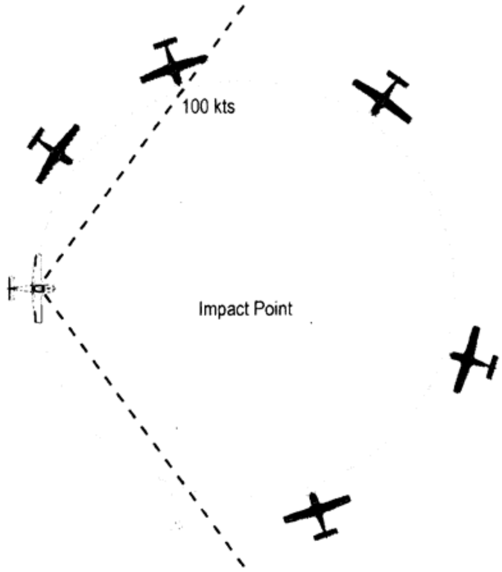


Figure 33. Relative orientation of aircraft closing to a collision point at 100 kts.

56. **Most likely angle of arrival**. It can be seen that most of the converging tracks would be detected by a scan only 60° either side of 12 o'clock.

[38] Forward of the line from the aircraft 3 o'clock, around to the 9 o'clock; the forward 180°.

At similar speeds, most conflicting traffic will appear within 60° of 12 o'clock



Aircraft with groundspeeds less than about 100 knots that converge as a result of manoeuvre are also likely to at least pass through the forward sector of the opposing aircraft, although the final angle of arrival can still be from anywhere from the 3/9 line forward, as depicted in Figure 34.

The final closing track of co-speed manoeuvring traffic may be beyond 60° of 12 o'clock but the approaching flight path is likely to transition the forward sector, or the conflict will pass astern.

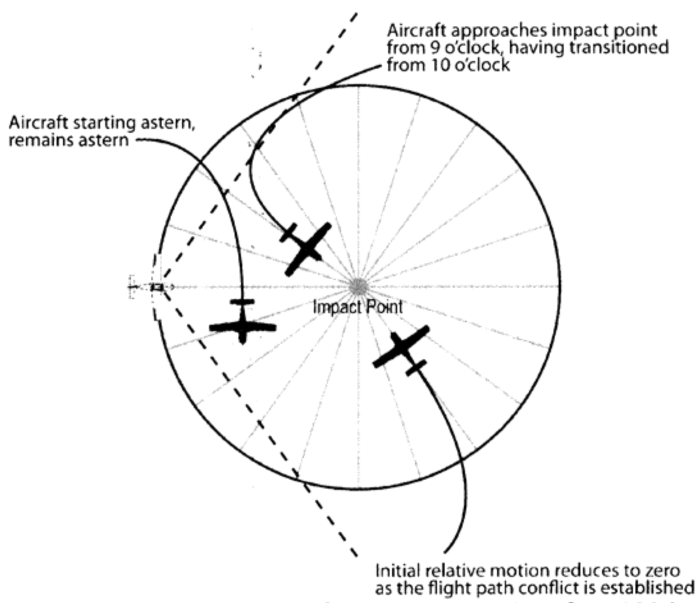


Figure 34. Relative orientation of manoeuvring aircraft at 100 kts or less.

This determination is consistent with advice contained within both the Tutor Flying Instructors Handbook and the Student Study Guide (Figure 35) which both state:

> c. The majority of your lookout time (about 70%) should be spent looking in the 10 to 2 o'clock sector. Research shows that the majority of mid-air collisions have occurred when the other aircraft was approaching from this sector. This also helps to avoid collision with the ground when at low level.

Figure 35. Extract from Tutor Training Manual.

The Panel noted, however, that this guidance is not reflected in the practical scanning technique that is advocated, which appears to give almost equal weighting to the entire visual field, with only the direct 12 o'clock receiving additional attention as a result of being the starting point for separate scans to the left and light (Figure 36).

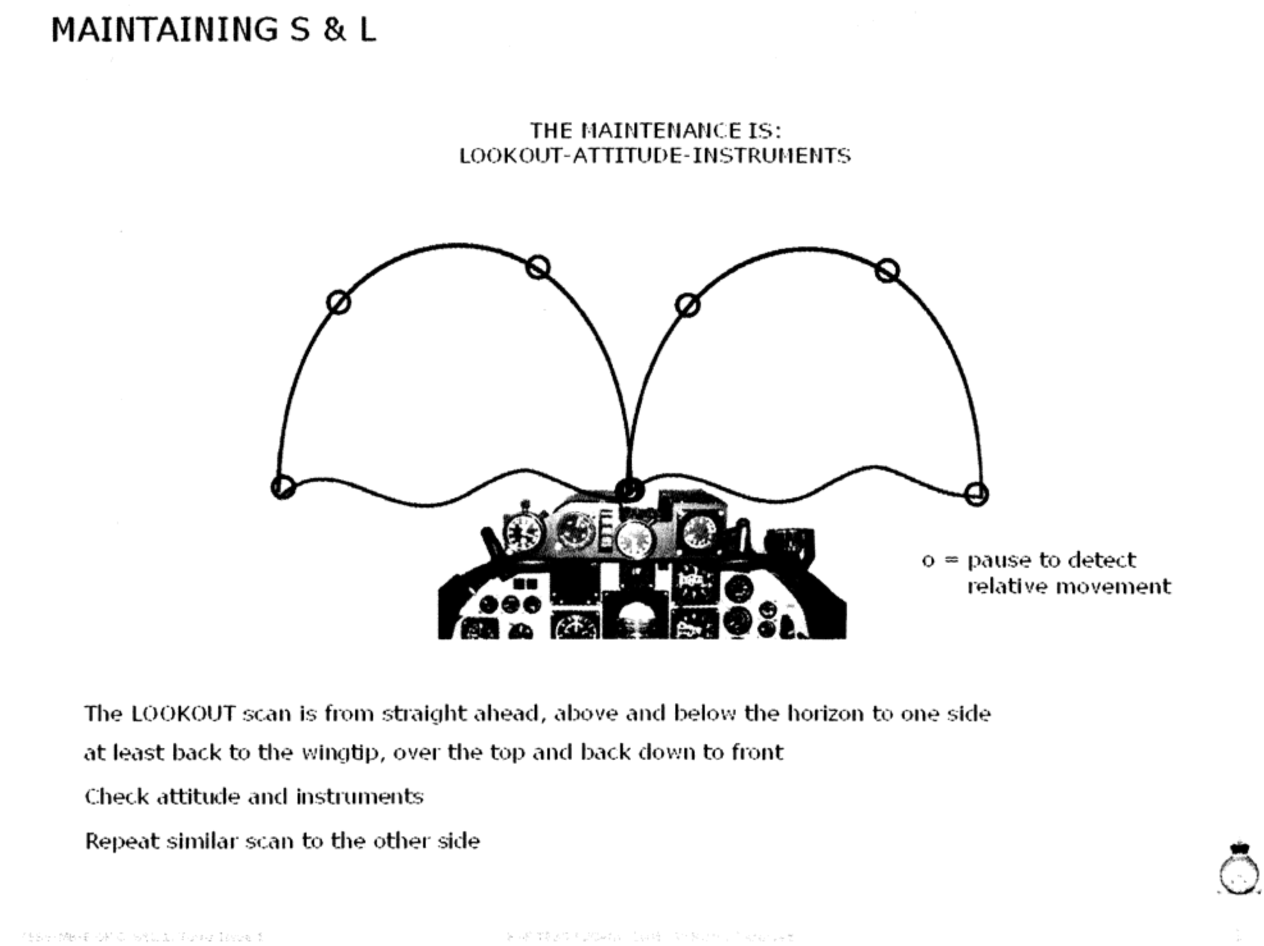


Figure 36. Schematic demonstrating the Lookout technique taught during Basic Flying Training on the Tucano.

Furthermore, traffic in the forward sector that appears outside of the instantaneous field of view directly forwards is as likely as not to remain undetected until the second scan is commenced which, commencing after the check of Attitude and Instruments, could be after an appreciable delay, especially for inexperienced students. Panel members also confirmed that the CFS approved technique had changed from a previously taught lookout scan that started at either the left or right extremity of vision, continued around to the other extremity of vision with deviations above and below the horizon, and then ended with a scan 'over the top' to finish at the starting point; such a technique would scan the forward sector in a shorter period but probably less frequently and affords no additional priority to the 12 o'clock. CFS advocates the current technique as more natural and more easily incorporated within the 'Lookout, Attitude, Instruments' cycle that forms the foundation of all flying training. The new technique is taught to new pilots as they pass through flying training and to prospective QFIs passing through CFS; the Panel could find no evidence to indicate that the change had been promulgated to Tutor pilots who were not students or QFIs, such as volunteer AEF pilots. Nevertheless, the Panel concluded that the current lookout scan was not the optimum to search for flight path conflicts and that a scan should be designed with the specific aim of covering most frequently and most thoroughly the areas from which flight path conflicts are most likely to appear; an example scan is at Annex AS.

Witness 16

Witness 14,15

Annex AS

57. **Pilot experience**. The Panel considered that both pilots were aware of the importance of maintaining a good lookout and would have received training in lookout techniques during their respective flying training.

a. **Pilot of G-BYUT**. As an AEF pilot who had not instructed Elementary Students, the Panel noted that the pilot of G-BYUT may not have received exposure to the lookout technique currently recommended in the Tutor Training Manual. AEF pilots must complete a conversion syllabus before flying air cadet passengers but this does not include specific instruction in lookout technique; experienced pilots are expected to have developed and be proficient at performing an effective lookout scan. In examining all possibilities, the Panel considered that the pilot of G-BYUT, who was very experienced and familiar with the local flying area, may have become complacent as a result of the generally low traffic density in the normal operating area and allowed his lookout to deteriorate. The Panel noted that the pilot of G-BYUT had elected to not take a radar service from Cardiff, preferring to operate autonomously and that this could indicate that he had complete confidence is his lookout scan or considered the risk of a flight path conflict to be remote. Nevertheless, the Panel noted the pronounced change of heading at 3200 ft which was consistent with the advocated Tutor technique of changing heading when passing every whole thousand of feet in a climb in order to clear the blind sector ahead of the nose while in a climbing attitude, accepting that other cockpit tasks sometimes interrupt this procedure and that it was acceptable to perform the lookout weave at other regular intervals. The Panel therefore concluded that the pilot of G-BYUT was most likely performing a lookout scan at least to the standard expected.

Annex I

Annex D

Annex E

b. **Pilot of G-BYVN**. The pilot of G-BYVN had only recently graduated from RAF Linton-on-Ouse where the need to lookout would have been routinely reinforced by the instructors; the technique advocated during training on the Tucano is consistent with the technique recommended for the Tutor. Hence, his habit patterns should have been correct, with the advantage of uncorrected eyesight and good peripheral vision. Nevertheless, the Panel considered that he might have become complacent with the benign AEF sortie profile and allowed his lookout scan to deteriorate. The departure track of G-BYVN indicated a change of heading as it passed 2000 ft which would be consistent with a lookout turn although other reasons, such as to observe or point out a ground feature, could not be discounted. The pilot of G-BYVN also elected to depart on a VFR profile and while this may have been an independent decision to adopt the least complicated profile, the Panel considered that he may have been less likely to choose a different option to the preceding aircraft for reasons of deferring to the experience of the pilot of G-BYUT or to realise the advantage of having both aircraft on the same frequency. The Panel noted a further weave at 2400 ft and although, as before, no firm assumptions could be made for the reason the Panel considered that the changes of heading provided reassurance that sound lookout procedures were being adhered to. The Panel concluded that the pilot of G-BYVN was most likely performing a lookout scan at least to the standard expected.

Annex E

Annex E

Summary of Human Factors conclusions

58. Among the Human Factors considered, the Panel concluded that:

a. Both pilots had an incomplete or inaccurate Mental Air Picture of the position, proximity and track of the other aircraft and that this was a contributory factor.

b. See and avoid is an uncertain method of ensuring traffic separation, owing to inherent limitations of the human visual system. Reliance upon See and Avoid was a contributory factor in the accident.

i. Both pilots had received extensive training in conducting lookout but that it might be possible to improve the technique further. Lookout technique may therefore have been a contributory factor in the accident.

ii. The cockpit workload within each aircraft is likely to have been low, and should have been comfortably within the capacity of each pilot. Narrowing of the visual field was therefore unlikely to have been a factor.

iii. Although the sorties were relatively benign, it is likely that the tempo of the sortie profile would have provided adequate stimulus to the pilots and low arousal levels were therefore unlikely to have been a factor.

iv. The pilots of both G-BYUT and G-BYVN were likely to have been subject to one or more of the limitations to which the human visual system is susceptible, each of which have the potential to delay or prevent visual detection of an approaching target. In the circumstances of this accident, the Panel considered that certain visual limitations were very likely to have contributed to the accident, although in isolation each limitation is assessed as a probable or possible factor:

(1) The pilot of G-BYUT may have had his sightline to G-BYVN interrupted by the canopy operating handle as he turned into the area of the collision; obscuration was therefore a probable contributory factor.

(2) As G-BYUT approached the collision point from the south, G-BYVN would have had a backdrop of white cloud. The white colour scheme of the Tutor, presenting little contrast with a bright background of cloud, was a probable contributory factor.

(3) Corrective Flying Spectacles, as worn by the pilot of G-BYUT, were a possible contributory factor in the accident.

(4) The pilot of G-BYVN would very likely have had difficulty observing the final approach of G-BYUT as a result of interruption of the sight line by the canopy arch and the adjacent cadet; obscuration was therefore a probable contributory factor.

(5) If not completely obscured, each aircraft would have appeared at the very edge of the cockpit transparencies from within the other aircraft for about the last 10-13 secs of flight leading to collision. Both pilots may have been subject to windscreen 'zoning' whereby lookout is biased towards the centre of the available viewing area, thus decreasing the chances of visual detection. Windscreen 'zoning' could not be discounted as a possible contributory factor.

(6) If not completely obscured, the pilot of G-BYVN may only have been able to acquire the approaching G-BYUT with one eye, decreasing the likelihood of visual detection. The Panel were unable to determine whether the influence of the blind spot and the reduced visual performance associated with monocular vision were factors in the accident.

(7) G-BYUT approached G-BYVN from the approximate direction of the sun. Glare from the sun would have made visual detection even less likely and was a possible contributory factor.

(8) The flight paths in the final secs leading to collision would have provided very little relative motion, reducing to zero, thus denying the most effective cue for visually detecting an object or target. This and other inherent limitations of the human visual system were possible contributory factors in the accident.

v. The Panel considered that the width of the Tutor canopy arch, the presence and size of the canopy spine and handle, and the lack of a 'go-forward' lever to enable the pilot to increase his range of in-cockpit movement, were contributory factors in the accident.

vi. The Panel considered that either pilot may have been distracted at a vital moment and although unlikely could not discount distraction as a possible contributory factor in the accident.

vii. A misplaced Mental Air Picture may have led the pilot of G-BYVN to concentrate his lookout in the wrong area but 'expectation', while possible, was unlikely as a factor in the accident.

c. The pilot of G-BYVN may have been visual with G-BYUT but that he did not recognise the threat and execute an effective evasive manoeuvre in the time available. However, most evidence indicated that the aircraft were in steady flight prior to the collision and therefore the Panel assessed that neither pilot saw the other aircraft in time to change the aircraft flight paths.

d. The condition of the occupants and the forces acting upon the aircraft post collision could not be determined precisely and the accident might not have realistically been survivable from the moment of collision. Any opportunity to abandon the aircraft and successfully deploy a parachute would have been very narrow:

i. The likelihood of a successful egress from the aircraft would increase (but could still not be assured) with increased familiarity with the abandon drill, to include actual operation of the canopy jettison mechanism. The lack of appropriate training was possibly an aggravating factor in the accident.

ii. The viability of an inexperienced air cadet successfully completing an abandon aircraft drill merits consideration:

(1) Air cadet training in abandoning an aircraft is minimal, amounting to a video demonstration only. The likely recall of such a brief, under conditions of great stress, is questionable. Cadet training in abandon aircraft drills was possibly an aggravating factor in the accident.

(2) The ability for some cadets to rise, unaided, from the Tutor cockpit sitting position in order to abandon an aircraft while wearing normal AEA and SE is doubtful. Aerodynamic and centripetal forces acting upon them could make this more difficult. Stature and strength had no bearing upon the circumstances of this accident as the cadets did not undo their seat harnesses but the Panel concluded that the issue merits attention.

iii. The chances of successfully locating and operating the parachute handle would increase with increased familiarity with the drill, to include practise at locating the handle, ideally while exposed to slipstream effects. The lack of appropriate training for this drill was possibly an aggravating factor in the accident for the pilot of G-BYVN.