

Air Accidents Investigation Branch

Department for Transport

**Report on the accident to
Hawker Hurricane Mk XII (IIb), G-HURR
1 nm north-west of Shoreham Airport, West Sussex
on 15 September 2007**

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

The sole objective of the investigation of an accident or incident under these Regulations shall be the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liability.

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Air Accidents Investigation Branch
Farnborough House
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September 2009

*The Right Honourable Lord Adonis
Secretary of State for Transport*

Dear Secretary of State

I have the honour to submit the report by Mr R G Ross, an Inspector of Air Accidents, on the circumstances of the accident to Hawker Hurricane Mk XII (IIb), registration G-HURR, 1 nm north-west of Shoreham Airport, West Sussex on 15 September 2007.

Yours sincerely

David King
Chief Inspector of Air Accidents

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- A Extract from ANO Article 80 and relevant CAA Publications
- B BBMF Training and Currency Requirements

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
agl	above ground level
amsl	above mean sea level
ANO	Air Navigation Order
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
°C,M,T	Celsius, magnetic, true
DA	Display Authorisation
DAE	Display Authorisation Evaluator
ft	feet
hp	horsepower
hrs	hours (clock time as in 12:00 hrs)
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
km	kilometre(s)
kt	knot(s)
MHz	megahertz
mph	miles per hour
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OCM	Organisational Control Manual
psi	pounds per square inch
RAF	Royal Air Force
rpm	revolutions per minute
UK	United Kingdom
UTC	Co-ordinated Universal Time (GMT)

Air Accidents Investigation Branch**Aircraft Accident Report No: 6/2009 (EW/C2007/09/08)**

Registered Owner and Operator: Spitfire Ltd

Aircraft Type: Hawker Hurricane Mk XII (IIb)

Registration: G-HURR

Manufacturer's Serial Number: 52024

Place of Accident: 1 nm north-west of Shoreham Airport, Sussex

Date and Time: 15 September 2007 at 1422 hrs
(All times in this report are UTC, unless otherwise stated)

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by Shoreham Airport Air Traffic Control (ATC) shortly after it occurred; an AAIB field investigation was commenced immediately.

The Hurricane aircraft, G-HURR, was taking part in a flying display and was following another Hurricane in a tail chase. Both aircraft flew past the spectators along the display line at a height of approximately 200 ft before tracking to the north-west and climbing. The lead Hurricane climbed to approximately 1,100 ft above ground level (agl), pitched nose-up about 45° and rolled to the left through 270°, before pulling into a right turn to rejoin the display line. The second Hurricane, which was approximately 700 ft agl, pitched nose-up about 15°, before rolling to the left. As it reached the inverted position, the roll stopped, the nose dropped and the aircraft entered a steep dive. It struck the ground, fatally injuring the pilot. The aircraft was destroyed by the ground impact and subsequent fire.

The pilot appeared to have attempted to follow the manoeuvre flown by the leading pilot. Although the airspeed was adequate, the aircraft had insufficient nose-up pitch attitude at the point of entry to ensure the safe execution of the manoeuvre in the height available. When the aircraft was inverted, the roll stopped, the nose dropped and insufficient height was available to recover from the dive.

The investigation identified the following causal factors:

- 1 The accident probably occurred as a result of the pilot attempting an unplanned rolling manoeuvre.
- 2 When the manoeuvre was commenced, the airspeed was adequate, but the nose-up pitch attitude was insufficient to enable the manoeuvre to be completed safely in the height available.
- 3 When the roll stopped in the inverted position, the aircraft's nose dropped rapidly and there was insufficient height available for the recovery manoeuvre the pilot attempted.

As a result of this accident six Safety Recommendations are made.

1 Factual Information

1.1 History of the flight

1.1.1 General

The pilot was to undertake three flying displays in Hurricane aircraft G-HURR, which he had previously flown and displayed. The first display was in Jersey; the second and third were part of a two-day airshow event at Shoreham Airport. He had agreed approximately one month before to fly the aircraft in the displays. On 12 September 2007, he collected the aircraft from Duxford and flew it to Jersey Airport. Another pilot, who was to fly a Hispano HA-1112 (Buchon) in the same display with the Hurricane, departed shortly before him. They met in Jersey and spent a quiet social evening together. The Hurricane pilot expressed his satisfaction at flying the aircraft again after a gap of about a year, during which time it had undergone a major refurbishment. He stated that he was completely “at home” in the aircraft but would be cautious with the display manoeuvres he would perform.

The flying display in Jersey took place, as planned, on 13 September. The scenario was that the Hurricane would engage in mock combat with a Junkers Ju 52 trimotor aircraft and would then be engaged by the Buchon. The Hurricane would then lead a tail chase which would include wingovers and level 360° turns in a dumb-bell shape being flown in front of the spectators along the seafront. No rolling manoeuvres were to be performed. The Buchon pilot considered that his aircraft had the more limiting handling qualities at the speeds to be flown and so the two pilots agreed that when the correct speed was achieved in the Buchon, its pilot would call on the radio for the Hurricane to execute the manoeuvre.

The Buchon and Hurricane initially departed to the north to practise their display, before performing it in front of the public. A safe display was carried out and as agreed, no rolling manoeuvres were performed. Both aircraft departed Jersey at the end of the day and flew to Shoreham independently.

On 14 September 2007, the Hurricane pilot spent a relaxing day at Shoreham whilst other aircraft and pilots, who were also part of the weekend flying displays, arrived. He spent a quiet evening with friends and again stated his satisfaction with the Hurricane before retiring to bed at about 2200 hrs.

1.1.2 Shoreham Airshow display briefings

1.1.2.1 Main display briefing

The main display briefing covering the day's events was held by the Flying Display Director at 0900 hrs on the morning of the accident. This was followed by a 'scenario' briefing by the leader of the airfield defence scenario. This briefing involved the pilots of the 11 aircraft taking part, which included the Hurricane pair (one of which was G-HURR) and two Bf 108s with which the Hurricanes were to display in mock combat. It was planned that when the two Bf 108 aircraft departed the display area, the Hurricanes would then display for four minutes. In the pilot's scenario briefing, the Hurricane pair display was described as:

'Hurri's tail chase with rolls. Brk to land. To crowd rear'

The Chief Pilot of the organisation displaying the Hurricanes asked the Hurricane pair to fly a 'celebration' style display, which was to include a barrel roll at crowd centre and a wingover at each end of the display line. He was aware that although one of the pilots was a serving Royal Air Force (RAF) pilot, flying the Hawk jet trainer, he had less experience on the Hurricane than the pilot of G-HURR. The Chief Pilot had therefore proposed a simple display taking account of this. The leader of the airfield defence scenario allocated the less experienced pilot on the Hurricane the role of leading the pair, in order to give him more freedom during the display. He considered that the pilot of G-HURR, with more experience on the type, would be better placed to follow the lead.

It was suggested by the Bf 108 pilots that the mock combat should comprise individual Hurricanes against individual Bf 108s, but both Hurricane pilots expressed dissatisfaction as there was no robust plan to ensure adequate separation between the two pairs of aircraft. It was then agreed that the two pairs would engage each other over the airfield, split vertically either side of 500 ft.

Following the scenario briefing, the two Hurricane pilots discussed their display. They agreed that the less experienced Hurricane pilot should lead the tail chase which was to include a series of flypasts, wingovers and rolling manoeuvres which the lead pilot referred to as 'Derry turns'¹. The lead pilot stated that he

¹ A 'Derry turn' is executed by rolling the aircraft 270° about its longitudinal axis in the direction opposite to that of the desired turn. When the roll angle reaches 270°, the roll is stopped and nose up elevator is applied to pull the aircraft into the turn.

would not perform loops or barrel rolls due to his lack of recent experience on the aircraft. The pilot of G-HURR responded that he was not happy performing low level aerobatics in the Hurricane at that stage due to his lack of recency on the aircraft. He also added that he would not be rolling the aircraft, which the lead pilot took to mean barrel rolls, as he thought they had already agreed to do Derry turns and a final climbing aileron roll. The lead pilot would manage the positioning of the aircraft and manoeuvres to be flown, as well as the timing of the display.

1.1.2.2 Post-briefing activities

After the briefing the two Hurricane pilots went to their aircraft to perform the pre-flight inspections. Having completed this, the lead Hurricane pilot surveyed the display area and realised that the plan for the mock combat with the Bf 108s was not feasible. With rising ground to the north and a minimum height restriction of 1,500 ft over the built-up area to the south and west, he felt that the two pairs of aircraft could not be deconflicted safely either side of 500 ft. The pilot of G-HURR agreed and the lead Hurricane pilot sought out the Bf 108 pilots and explained his concerns to them over lunch. After some discussion, it was agreed that a simplified profile would be flown. The two Hurricanes would fly in from the north as a pair and be 'attacked' by the pair of Bf 108s. The roles would then be reversed, with the Hurricane pair engaging the Bf 108s. To simulate a 'kill' the lead Bf 108 would emit smoke by introducing oil into the engine exhaust system and the pair would then turn downwind to land, leaving the Hurricanes to commence the tail chase sequence.

After lunch, the two Hurricane pilots met to rebrief their display in detail. It was agreed that once the Bf 108s had departed, the lead Hurricane pilot would lead the tail chase through a series of turns and flypasts. In order to provide the following Hurricane with a greater power margin, it was agreed that the leader would set 2,650 propeller rpm and five psi of supercharger boost and fly the entire display with that fixed power setting, managing the aircraft energy accordingly. The following pilot would have six psi of boost available to him. The lead pilot stated that he would limit his manoeuvring as previously discussed and the last pass to break downwind would be a climb and aileron roll. The pilot of G-HURR had no questions and the two pilots conversed for about 20 minutes prior to attending the final display briefing.

1.1.2.3 Final display briefing

The final display briefing was held on the flight line at about 1300 hrs by the Chief Pilot, who invited comments. The lead Hurricane pilot informed him that they would not be executing barrel rolls at crowd centre, but would perform flypasts and wingovers instead. He stated that he would perform a Derry turn on one of the wingovers, if appropriate, and would finish with a climbing aileron roll onto the downwind leg. The pilot of G-HURR is reported to have said that he would not be performing any roll manoeuvres but was happy with the rest of the display.

As all of the briefings were conducted verbally, no written record of them was available.

1.1.3 The accident flight

Both Hurricane pilots started their aircraft and taxied to Runway 20 for departure. A display frequency of 125.4 MHz was available but apart from initially checking in on that frequency, the pilots had not planned to communicate unless it became necessary. Following a short delay for landing aircraft, both Hurricanes lined up for takeoff. The pilot of G-HURR used the main runway and the lead pilot used the grass runway parallel to Runway 20.

The two Bf 108s were engaged in a mock attack of the airfield, accompanied by pyrotechnics. At the appropriate moment, both Hurricanes took off and flew a series of pre-planned turning manoeuvres, initially acting as targets for the Bf 108s. The Hurricanes and Bf 108s then reversed roles. When the allotted time came to complete that element of the display, the Bf 108 leader emitted smoke and both Bf 108s departed the display area to land.

The Hurricanes then commenced the tail chase element of the display. Prior to the accident manoeuvre, the lead Hurricane pilot led the pair in an oblique 360° turn to the left. They flew past the crowd in a northerly direction with about 200 metres separation between the two aircraft. Once clear of the airfield boundary, both aircraft turned left through approximately 45°, rolling out on a north-westerly heading. The leader eased his aircraft's nose up to gain height, his track now gaining him separation from the display line. This allowed sufficient room to turn back on to the display line without passing through it. As the IAS reduced to 200 kt, he raised the nose higher above the horizon, checked forward and initiated a roll to the left. From a video recording his height at that point was estimated as approximately 1,100 ft. The ground in this area rises steeply up towards Lancing Hill, which is 265 ft amsl. The following

Hurricane also initiated a gentle climb, but only climbed to about 700 ft agl. As the lead Hurricane's roll attitude passed the inverted, the second Hurricane also rolled to the left. Its nose-up pitch attitude was considerably less than that of the lead aircraft on commencing the roll. The leader continued rolling to the left and on reaching 270°, stopped the roll and applied up elevator to pull through to the right, thus completing a Derry turn to the right to return to the display line. The pilot of G-HURR appeared to stop the roll as his aircraft became inverted and its nose then dropped rapidly. The aircraft entered a dive and struck the ground in a steep nose-down attitude, fatally injuring the pilot. The aircraft wreckage caught fire shortly after impact.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	-	-
Serious	-	-	-
Minor/none	-	-	-

1.3 Damage to aircraft

The aircraft was destroyed by the ground impact and post-impact fire.

1.4 Other damage

There was no other damage

1.5 Personnel information

1.5.1 Commander

Male	Aged 49 years	
Licence:	Private Pilot's Licence	
Aircraft ratings:	Single and multi-engine landplanes not exceeding 5,700 kg	
Medical Certificate:	Class 2 medical certificate, issued on 27 October 2005	
Flying experience:	Total:	1,115 hours
	On type:	186 hours
	Last 90 days:	16 hours
	Last 28 days:	9 hours
Previous rest period:	38 hours	

The pilot was employed as the manager of a small airfield at which a private collection of classic aircraft was based. The Hurricane G-HURR was part of that collection and he first flew it on 26 April 1998, shortly after it was acquired by the owner. During that period of ownership, the pilot recorded 186 hours on the aircraft in one of his logbooks and that he had flown 108 displays. He held a valid CAA Display Authorisation.

G-HURR was sold in 2006 and the pilot delivered it to its new owner and operator at Duxford on 26 September 2006. The aircraft was to undergo a major overhaul and rebuild before the 2007 display season.

Since the delivery of G-HURR to Duxford, the pilot had recorded flying a number of different types of aeroplanes and helicopters, as follows:

Aircraft type	Hours flown	Number of flights
Jungmeister	11.9	20
Arrow Active	4.5	8
C100	.5	1
DR1	6.0	8
Robin	4.5	10
Total aeroplane flying hours	<u>27.4</u>	<u>47</u>
SA340 Gazelle	1.0	1
Robinson R22	9.5	9
Total helicopter flying hours	<u>10.5</u>	<u>10</u>
Total Flying hours	37.9	57

Table 1

Pilot's flying record since September 2006

In addition to the flying recorded in his logbooks, it was possible to establish from ATC aircraft movement records, the hours he flew on G-HURR after departing Duxford to perform the flying displays. These showed that at the time of the accident, he had flown 3 hours and 16 minutes since departing Duxford. This included the display at Jersey, which was 42 minutes in duration.

The pilot was believed to have been mainly self-taught in his aerobatic skills. No record of any formal training course was available but he was described by associates as a competent basic aerobatic pilot. The previous owner of G-HURR considered that when displaying the Hurricane, the pilot probably would only execute four basic aerobatic manoeuvres. These were: half Cubans, oblique loops, wingovers and aileron rolls with a significant upward vector. He had performed displays since 2002 in several different aircraft types, including the Hurricane, Jungman, Jungmeister, Mew Gull, Arrow Active, replica Fokker DR1 and Magister.

There was no evidence to show that the pilot of G-HURR had previous experience of performing aerobatics while flying the Hurricane in a tail chase, nor was any firm evidence found of him having previously performed a Derry turn during displays in the Hurricane. Some people who knew him well stated that he had never performed a Derry turn. However, the Chief Pilot of the organisation displaying the Hurricanes reported that he had seen him perform this manoeuvre during a display some time ago.

From discussions with pilots involved in displaying similar aircraft, it appears the pilot was well respected for his approach to safety. He showed due regard for the aircraft and confined his displays to operating within its limitations, as well as his own.

1.5.1.1 Display Authorisation

In order for the pilot to display G-HURR, he was required to hold a current Display Authorisation (DA), issued by the UK Civil Aviation Authority (CAA). The DA sets out the classes of aircraft, the categories of aerobatic manoeuvre, minimum heights, formation and tail chase participation which may be flown. The pilot held a current DA which was renewed by the Display Authorisation Evaluator (DAE) on 7 June 2007.

1.5.1.2 Display Authorisation renewal

The pilot had flown a demonstration display in a Jungmeister with a colleague who was flying a second Jungmeister, in order to renew his DA. He was observed flying in formation and in a tail chase with the other aircraft, which also included some aerobatic manoeuvres, followed by a solo aerobatic demonstration. There was no requirement to demonstrate, for the purposes of the DA renewal, all the manoeuvres which he intended, under its privileges, to fly in displays.

The DAE assessed the flight as demonstrating:

'Satisfactory formation duo flown in a Jungmeister. This included a separate solo aerobatic display, to a good standard.'

Civil Aviation Publication (CAP) 403 states:

'Where multiple types or categories are held on a DA it is not necessary to renew each individual type or category. The DA is renewed by demonstrating on any one of the authorised aircraft types or categories.'

The categories for single engine piston aircraft are:

- A - Less than 200 horsepower (hp)
- B - Between 200 and 600 hp
- C - Exceeding 600 hp

The DA was renewed in the same aircraft categories and to the same limits as those which had been previously authorised. The Jungmeister is a Category A aircraft but renewing his DA on that aircraft also permitted him to display aircraft in any other category including the Hurricane.

The pilot's DA permitted him to lead or be a member of a formation or tail chase. When flying the Hurricane, he was authorised to be a member of a formation of an unlimited number of aircraft and to lead a formation of up to four aircraft. When carrying out close formation flying, he was limited to carrying out 'Basic' category manoeuvres. These are defined in CAP 403 as:

'Gentle formation manoeuvring where the bank angle should be limited to approximately 30 degrees and the pitch angle to 30 degrees. Formation manoeuvring should be smooth and progressive.'

A tail chase is defined in CAP 403 as:

'A number of aircraft following a leader in loose proximity, in line astern, whilst the leader carries out a series of manoeuvres of an aerobatic or semi-aerobatic nature. Each aircraft in turn will generally follow the leader's flight path but retain a high degree of individual decision-making over the exact path to be taken. Separation distances vary from 50 to 200 metres.'

Unlike close formation flying, no manoeuvring categorisation or limitations (basic, intermediate or advanced) are defined for pilots carrying out tail chases.

The pilot's aerobatic display category was 'Standard' with a minimum height permitted of 300 ft. The Standard aerobatic category manoeuvres are defined in CAP 403.

In order to exercise the privileges of a DA the pilot must meet certain recency requirements which are set out in CAP 403. These are:

'Recency'

'In addition to a valid Certificate of Test and Competence, a Display Pilot is required to meet certain recency requirements before his DA is valid. In the 90 days preceding a demonstration at a Flying Display for which an Article 80 Permission is required, a minimum of 3 full display sequences must have been flown or practised, with at least 1 display sequence flown or practised in the specific type of aircraft to be displayed'.

1.5.2 Lead Hurricane pilot

The pilot leading the Hurricane pair was a serving RAF pilot flying the Hawk jet aircraft. His total flying experience was 7,000 hours of which 180 hours had been flown on the Tutor, a piston engine aircraft; the rest were on four military jet types. He had accumulated 5,520 flying hours on the Hawk and had been an RAF Hawk display pilot for three seasons, from 2003 to 2005. In 2007 the pilot had qualified to fly two civilian-registered jet types, the T33 Silver Star and the F86A Sabre. During the 2007 display season, he displayed the F86A Sabre on four occasions.

In order to become eligible to fly large piston engine fighter aircraft, such as the Hurricane, he had undertaken a programme of training, mainly to further develop his 'tailwheel' experience. This took account of his flying background and previous tailwheel experience.

Since qualifying to fly the Hurricane, the pilot had flown 7 hours 45 minutes on the type, which had included four displays. His DA permitted him to carry out displays of the Hurricane aircraft and to lead or be a member of a formation or tail chase.

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Canadian Car and Foundry Company
Type:	Hawker Hurricane Mk XII
Aircraft Serial No:	52024
Date of Construction:	1943
Engine:	Rolls-Royce Merlin Mk 225 (Canadian)
Propeller:	Hamilton Standard 23EX50-505
Total airframe hours:	252 hrs since restoration in 1996

This mark of Hurricane was similar to the Mk IIb that was built in the United Kingdom. The fuselage was of a tubular frame structure, with the forward fuselage covered in aluminium alloy sheet and the aft fuselage with wooden formers and stringers covered in fabric. The 40-foot span wing featured high tensile steel spars and aluminium alloy skins. The primary controls were actuated by conventional cables and pushrods. The flaps and landing gear were hydraulically operated and the wheel brakes were pneumatically operated.

Following a total restoration, the aircraft flew again in 1996. It underwent further restoration during the winter of 2006/07, with an annual check in May 2007.

The engine, which was identified with constructor's number V335561, had been overhauled in 1996 and was given a life of 400 hours until next overhaul. It was subsequently overhauled in 2005 after 190 hours. The constant-speed propeller, serial number N123321, was last overhauled in 1999, when new blades were fitted. The propeller pitch angle operating range was 28° to 68°. The aircraft, engine and propeller all received an annual inspection in May 2007, at which time the aircraft had accumulated 239 hours since restoration in 1996.

Although the aircraft was recorded on the UK Civil Register as G-HURR, it was not required to display those markings. Instead, it carried squadron letters AE-C and military serial number BD707.

The aircraft had a current Permit to Fly and was being operated in accordance with the requirements of CAP 632 'Operation of 'Permit-to-Fly' Ex-Military Aircraft on the UK Register' (see Appendix A).

1.6.2 Weight and Centre of Gravity

Calculations based on estimated fuel weight at the time of the accident showed that the aircraft was being operated within the permitted weight and balance envelope.

1.7 Meteorological information

The weather at the time of the accident was good. The weather observation at Shoreham at 1350 hrs was: surface wind 160° at 5 kt, visibility in excess of 10 km, few clouds at 4,200 ft with an Outside Air Temperature (OAT) of 20°C, a dew point of 13°C and a sea level pressure of 1024 hPa. The accident occurred at 1422 hrs and the weather had not changed since the observation.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

Shoreham airport is located 1 nm west of Shoreham-by-Sea at N50 50.13 W000 17.83. The airfield has four runways, two of which are orientated 02/20, and the others 07/25 and 13/31. The asphalt-surfaced Runway 02/20 is the main runway, 1,036 metres long with a width of 18 metres. A parallel grass runway is located to the east of the main runway, also orientated 02/20 and is 700 metres long with a width of 18 metres. The other runways are also grass. The airfield elevation is 7 ft amsl. The display line for the flying display was the centreline of the main runway.

1.11 Recorded data

Members of the public attending the airshow provided a large number of video and still photography images to the investigation. An analysis of evidence showing the accident manoeuvre was performed by a specialist organisation and the AAIB. Due to the distance of G-HURR from the various camera positions, it was not possible to correlate the control surface deflections with aircraft movement with any reasonable degree of certainty.

It was determined from this analysis that the two Hurricanes flew past the

crowd at approximately 200 ft agl, separated by a distance of about 200 metres, before climbing. The lead Hurricane pilot entered a rolling manoeuvre at about 1,100 ft agl by pitching the aircraft nose up about 45° at an entry speed of about 220 kt and then rolling 270° to the left. At about 700 ft agl the pilot of G-HURR pitched the nose up about 15°, (estimates of pitch angle are +/- 7° due to the limitations of the video recording) at a speed of about 190 kt (218 mph). The pilot of G-HURR initiated a roll to the left 2.8 seconds after the lead Hurricane pilot commenced his manoeuvre. On reaching the inverted position the roll stopped, at which point the nose had pitched down to about 13° below the horizontal. The aircraft's nose fell rapidly and continued to pitch 'up' (in aircraft axes) through the vertical, to 51° nose-down at 1.36 seconds before impact. The rate of nose-up pitching then appeared to increase and the right wing dropped. At 0.32 seconds before impact, the aircraft pitch attitude was 39° nose-down. Its mean speed over the final 0.64 seconds was estimated at 188 kt, +/-18 kt.

Table 2 summarises the results of the analysis.

There was also photographic evidence from a still camera of the aircraft at approximately tree level, immediately prior to it striking the ground. On none of these photographs, nor any of the other media, was there any evidence of any anomalies with the aircraft.

1.12 Aircraft and site examination

1.12.1 Accident site examination

The wreckage was located in a corner of a grassed field, 1 km north-west of the northern end of the Shoreham Airport and approximately 250 metres from Lancing College. The grass was dry and the ground was firm.

The initial impact marks were consistent with the aircraft striking the ground in an approximately 45° nose-down attitude, on a heading of around 170°(M). A 40-foot long ground mark was visible at the start of the wreckage trail, consistent with both wing leading edges having struck the ground. There was a large ground impact mark up to 35 centimetres in depth, approximately three metres further along the wreckage trail, in which the heavily damaged three-bladed metal propeller was located. Further inspection of the propeller revealed that one blade was particularly badly damaged and had rotated at the hub beyond the normal blade pitch range. The other two of the three propeller blades had heavy leading edge scoring and further damage consistent with significant engine power at impact.

SUMMARY of RESULTS					
TIME BEFORE IMPACT (Seconds)	ANGLE OF BANK (Degrees +/- 10°)	ROLL RATE (Degrees/sec)	PITCH (Degrees +/- 7°)	HEIGHT (Metres - estimated)	CROPPED VIDEO FRAMES
8.12	6	45° degrees per second	+15	250	
7.16	53		+13	250	
6.20	98		+5	250	
5.24	149		-13		
4.28	182		-54		
3.32	188		-78		
2.32	187		-80		
1.36	190		-51		
0.32	194		-39		

Table 2

The main wreckage of the aircraft was located 22 metres from the initial impact point, with the majority of the aircraft being upright and with the fuselage pointing due north. The left wing, the inboard section of the right wing (including the right landing gear leg), and empennage were still attached to the heavily disrupted fuselage. The right wing outboard of the landing gear attachment point had detached. The engine was located 17 metres from the initial impact point. The supercharger had detached and the oil sump had

been ruptured. The majority of the wreckage was severely disrupted and had been subject to a post-impact fire. Several of the outlying items of wreckage were coated in oil, consistent with significant quantities of oil having been thrown from the damaged engine. The furthest piece of wreckage was located 72 metres from the initial impact point.

The aircraft was fitted with several instruments which had mildly radioactive luminescent paint on the dials, and hence the wreckage was assessed for radioactivity whilst in the field. Several of the more badly burned items in the cockpit were found to have radiation levels that posed an identifiable but manageable health hazard.

1.12.2 Detailed examination of the wreckage

1.12.2.1 Controls examination

Examination of the rudder, rudder trim, elevator, elevator trim, aileron and throttle control runs did not reveal any evidence of control malfunction. All the damage observed was consistent with the effects of the ground impact and subsequent fire. Given the extent of the damage to the wreckage, it was not possible to determine control surface trim settings with any degree of confidence.

1.12.2.2 Engine examination

The engine was disassembled and inspected at the AAIB with the assistance of engineers with experience of the Rolls-Royce Merlin engine.

Most of the sump had been destroyed, which facilitated inspection of the crankshaft, main bearings and big end bearings, all of which appeared to have been in a satisfactory condition before impact, and which had been correctly wire locked. A baffle plate in the sump was damaged and had been dragged towards one of the cylinders by the big end of a connecting rod; this suggested that the engine was turning at the moment of impact.

The spark plugs were in good condition and their appearance suggested that the correct fuel/air mixture was being burned. Each of the 12 cylinders was examined internally and, with the exception of the first cylinder on the left side of the aircraft ('A' bank No 1 cylinder) which had been subject to significant impact damage, all the cylinders and valves appeared capable of operating normally. The camshafts and cam followers were all in satisfactory condition, and the engine's lubrication system appeared to have been working

satisfactorily. Both magnetos had signs of cracking of the internal insulation material but, given the condition of the spark plugs, this damage was considered to be impact-related.

The carburettor was damaged and had become detached. There was minor debris in the fuel inlet filter, possibly consistent with the disruption during impact but this was unlikely to have caused a restriction in fuel flow to the carburettor. The butterfly valves were in the 'idle' position but there was significant disruption to the control linkages which precluded an accurate assessment of the throttle position.

1.12.2.3 Propeller examination

The propeller was stripped under AAIB supervision at an organisation with experience of this type of propeller. The internal mounting lug for the most damaged blade had fractured. However the lugs for the remaining two blades were intact and indicated that these blades were at a pitch angle of 37° at impact. The examination revealed that the mechanism was well lubricated and that there was no evidence of a malfunction that could not be explained by the impact with the ground.

1.13 Medical and pathological information

A post-mortem examination revealed that the pilot had died of severe multiple injuries, all of which were consistent with the impact. The crash was non-survivable and, within the limits of the autopsy, no natural disease which could have caused or contributed to the accident was identified. The toxicological examination did not reveal any factors which might have influenced the performance of the pilot.

1.14 Fire

There was a severe post-impact fire.

1.15 Survival aspects

The impact was not survivable.

1.16 Tests and research

Not applicable.

1.17 Organisational and management information

1.17.1 Operational management

At the time of the accident, G-HURR was being operated in accordance with CAP 632 (see Appendix A) as part of a fleet of aircraft. The operator's revised Organisational Control Manual (OCM) was agreed with the CAA in February 2007 and the pilot of G-HURR on the accident flight had signed the signature sheet to say he had 'read and understood' the OCM on 12 September 2007.

Section 2 of the operator's OCM contains information relating to aircrew qualifications and experience. The following extracts are of relevance:

2.1 Currency

DA Pilots are to maintain display currency as per CAA/DA minima as detailed in CAP 403. If no flight of any type has been undertaken for 6 calendar months, a period of training/ refresher training is to be completed as detailed below.

2.2 Training

Pilots new to type, or who have exceeded 6 months since last flight on type, are to undertake the following training:

2.2.1 Full briefing on aircraft systems, handling and limitations.

2.2.2 Brief/refresh on documentation, which is to include:

OCM

CAA CAP 403 and associated documentation

Appropriate Flight Manual

Engineering documentation

Administrative procedures

2.2.3 Issue or revalidate pilot maintenance authority (turn round and walk round etc).

2.2.4 Cockpit brief and supervised start.

2.2.5 Supervised solo flight (may be preceded by a dual check in Spitfire T9, Harvard or other suitable aircraft at the Chief Pilot's discretion).

2.2.6 General handling – to include stalling and aerobatics

2.2.7 Practice display (if DA qualified) to pre-arranged limits'

The pilot of G-HURR had not flown the Hurricane for over 11 months and was therefore no longer current with respect to the training requirements set out in paragraph 2.2. No records were provided by the operator of the pilot having carried out the training and other requirements. However, the operator's Chief Pilot had specifically given him the long sector from Duxford to Jersey to allow him to reacquaint himself with the aircraft. Given the pilot's experience on the Hurricane, the Chief Pilot considered that he met the OCM requirements in principle.

1.17.2 CAA Civil Air Display Review

In 1996, the CAA set up the Civil Air Display Review Group which comprised members from the CAA and industry. It was set up partly as a response to the number of accidents that occurred during 1996 and partly because it had been some time since there had been a detailed review of display procedures.

The Group was tasked with studying the safety record of UK civil air displays since 1 January 1990, in particular the regulations and procedures governing the organisation and conduct of displays, the approval of display pilots and the operation of display aircraft with reference to the safety of spectators, display pilots, crews and other third parties.

The Group produced its report on 22 April 1997, as a result of which a number of safety improvements were introduced, including changes to CAP 403 and other areas associated with display flying.

1.18 Additional information

1.18.1 Legal Requirements

The CAA has the responsibility for the regulation of Flying Displays and the issue of Permissions and Display Authorisations to organisers and participating pilots.

A flying display is defined in Article 155, Interpretation, of the Air Navigation Order (ANO) as follows:

“Flying display” means any flying activity deliberately performed for the purpose of providing an exhibition or entertainment at an advertised event open to the public.’

The law covering flying displays is set out in the ANO, Article 80 ‘*Flying displays*’ and addresses the requirements placed on the CAA, event organisers and pilots. Appendix A presents extracts from the Article which cover the requirements which relate to the accident flight.

1.18.2 The accident manoeuvre

The lead Hurricane pilot stated that he had briefed the pilot of G-HURR that he would execute ‘Derry turns’ during the Hurricane pair display. The manoeuvre involves rapidly rolling the aircraft in the opposite direction to that of the intended turn; once the aircraft has rolled 270°, nose-up elevator is applied to pitch the aircraft into the turn in the desired direction. According to various sources, the manoeuvre may also be referred to as a ‘Derry wingover’ or a ‘rolling reversal’.

To perform this manoeuvre the nose of the aircraft must be pitched up considerably before commencing the roll, to ensure the aircraft’s flight path has an initial upwards vector and sufficient height and airspeed must also be available. The ailerons are applied to roll the aircraft in the opposite direction to that of the desired turn, with no elevator inputs and only small rudder inputs to counter any adverse aileron yaw. The aircraft rolls about its longitudinal axis following a quasi-ballistic flight path. When the roll angle reaches 270°, the roll is stopped and nose-up elevator is applied to pitch the aircraft into a turn in the opposite direction to that of the initial roll.

As the aircraft is rolled, the weight of the aircraft acting at the centre of gravity causes the nose of the aircraft to drop continually relative to the horizon, so that on completing the manoeuvre, the aircraft may be in a significantly nose-down pitch attitude. This is the reason for requiring the aircraft to have a suitable upwards trajectory prior to entering the manoeuvre.

If elevator or rudder inputs are made whilst the aircraft is rolling, the aerodynamic forces generated may cause the roll to ‘barrel’ so that the aircraft’s nose describes a circular path around the axis of roll. An important consequence of this is that if nose-up elevator input is present during the manoeuvre when the aircraft becomes inverted, the lift force generated by the wings combines with the weight, increasing the rate at which the nose drops.

If the roll is stopped with the aircraft inverted, down elevator (forward stick) must be applied quickly to arrest the pitch rate, before rolling wings level, after which the aircraft can be recovered to level flight. If this action is not taken, the aircraft will rapidly enter a steep dive, from which considerable height is required for recovery.

The 'Pilot's Notes' (AP 1564 B & D) for the operation of the Hurricane recommend a roll entry airspeed of 220 to 250 mph IAS (191 to 217 kt).

1.18.3 Previous display accidents

The investigation reviewed several previous accidents which had occurred during flying displays. A number were identified, which appeared to have factors in common with the G-HURR accident.

The factors considered common to these accidents were:

- The pilot was qualified to carry out the display manoeuvres being undertaken;
- The entry height, energy (airspeed) and/or technique for flying the manoeuvre was incorrect;
- Insufficient height was available to recover from the manoeuvre when problems occurred.

Additional issues which may have contributed to the accidents were:

- Low currency and high familiarity with the aircraft type being flown;
- Human performance and its limitations;
- Performing manoeuvres inappropriate to the aircraft type at low level.

1.18.4 Human factors

The CAA Human Performance and Limitations syllabus is very comprehensive. It is not intended to reproduce it in detail within this report but certain aspects appear to have relevance to this accident and are presented as follows:

An individual develops skills based on their experience and these are stored in the long-term memory. They are gained through practice or repetition of a task until competence is achieved. These skills provide responses to situations that the person encounters. In addition, sensory perception, in particular

sight, hearing, balance and touch provide the pilot with situational awareness on which he bases a response. The ability to detect, interpret and deliver a solution to a situation is strongly affected by physical condition and available mental capacity to process information.

There is a direct correlation between the level of stress that a pilot is experiencing and the performance he produces. Figure 1 below illustrates the level of performance against the stress being experienced. The level of stress affects the degree of arousal or alertness.

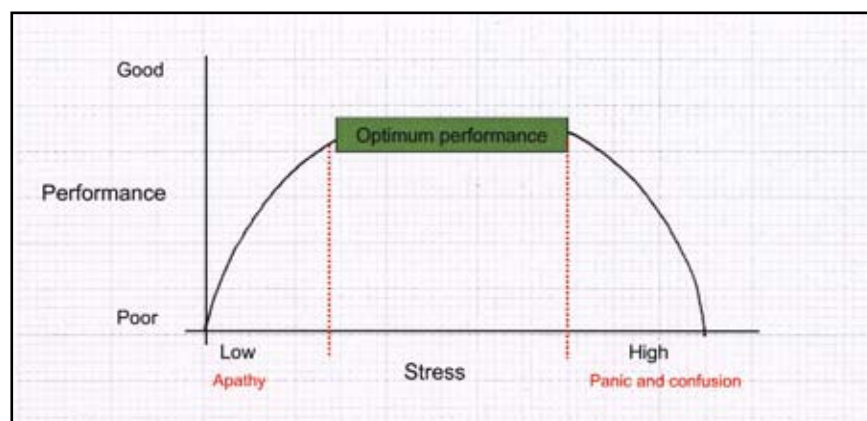


Figure 1

How well individuals cope with stress is determined by their personality and health. Moderate levels of stress stimulate mental activity and produce optimum levels of performance. Low levels of stress create underarousal and can lead to apathy, whilst high-stress situations can create panic and confusion. Sudden, critical situations can cause a person to rapidly move from apathy to panic and/or confusion without attaining their optimum performance. These situations can create physical changes, such as increased heart rate and narrowing of vision.

In order to respond to a situation, the brain must go through a sequence of operations. The receptors must convey the situation to the brain. The brain must register and prioritise the elements of the situation and then, from memory or knowledge, deliver a response. The response is analysed for correctness and if the situation is resolved, the matter is closed. If not, the process is repeated until a successful resolution is achieved. At times of optimum performance this all happens within a fraction of a second, but in high-stress situations with large amounts of possibly conflicting information, accurate decisions take much longer, but the criticality of the situation may demand a rapid response. The success of the whole process relies on accurate

information from the receptors and the interpretation of that information by the brain. It is the potential for misinterpretation of information that is one of the greatest limitations of human performance and which can lead to incorrect decisions being reached in a critical situation. This is compounded by the fact that the brain's ability to process information can be severely limited in high-stress situations.

In the tail chase scenario, the point of focus is the lead aircraft. The ability of the following pilot to carry out the same manoeuvre will influence the level of stress he experiences and thus his resulting performance. Losing sight of the lead aircraft during a manoeuvre will require the pilot of the following aircraft to identify his situation, either completing the manoeuvre, or carrying out some other appropriate action. The following pilot must still retain a high degree of situational awareness of factors such as airspeed, height and aircraft attitude. At low height and with time pressures, such decision making must be very rapid in an environment, possibly, of conflicting information.

It is also possible in certain situations for a pilot to experience spatial disorientation, which can lead to a severe degradation in the pilot's performance and a loss of situational awareness.

1.18.5 RAF operation of historic aircraft

The pilot training and currency requirements for the operation of historic aircraft by the RAF are presented in Appendix B for reference purposes. Whilst no attempt is made to suggest that this would be the best approach for civil operation of these aircraft, elements of the training and currency requirements may be of relevance.

2 Analysis

2.1 General

The aircraft had a current Permit to Fly and was properly maintained. No evidence was found of any defect that could have caused or contributed to the accident. The pilot was properly licensed, held a current Class 2 medical certificate, and was properly authorised to display the Hurricane. The weather was good, he had carried out recent displays on other types and he had displayed the Hurricane in Jersey two days before the accident. He was in good health, in good spirits, and experienced at flying and displaying the Hurricane.

2.2 The accident manoeuvre

The pilot of G-HURR was pleased to be flying the Hurricane again after a one year break and wished to deliver a safe performance. He had stated that he would be cautious with the type of manoeuvres he would perform. Although he had declined to carry out rolls, it was whilst apparently attempting a rolling manoeuvre that the accident occurred.

He had clearly stated during briefings that he would not perform any rolling manoeuvres during the display. That he stated this on a number of occasions would seem to indicate that this was very clear in his mind prior to the display. Nevertheless, he appears to have made the decision to perform a rolling manoeuvre, which led to the accident. The reasons why he may have attempted this cannot be determined with any certainty, but possible scenarios are considered.

One possibility is that the pilot changed his mind either just before or during the display, deciding that he was capable of performing the rolling manoeuvre and therefore made a conscious decision to roll the aircraft. It is not known for certain what manoeuvre the pilot intended to perform, but if it was his intention to perform a Derry turn, for this hypothesis to be plausible, it would have required him to have previous experience of performing the manoeuvre. To have a high probability of completing this manoeuvre successfully at such a low height, he would need to have been fully aware of the aircraft's situation and to be well-practised in performing the manoeuvre. The Chief Pilot stated that he had seen the pilot perform a Derry turn before, but there was no evidence to suggest that he had done so recently. Others who knew the pilot well stated that he had never performed this manoeuvre before. The pilot was well aware of the fact he lacked recency in displaying the Hurricane and because of this, he had chosen not to roll the aircraft during the display at

Jersey. On this basis it would seem unlikely that there would have been any significant degree of premeditation by the pilot to perform the manoeuvre.

Another possible explanation for the pilot reversing his decision not to roll, is that he may have felt under personal or social pressure to perform a good display and therefore felt compelled to perform the manoeuvre.

If the rolling manoeuvre was not premeditated, the decision to perform it may have been taken impulsively. It is possible that the pilot impulsively decided to perform a rolling manoeuvre without having been influenced by the actions of the lead pilot. Alternatively, he may have been focussed so intently on the lead Hurricane that he was drawn into performing the rolling manoeuvre as a consequence of trying to follow the lead aircraft, to the detriment of his own situational awareness. His involvement in the Hurricane tail chase may therefore have been a significant contributory factor.

All of these possibilities require the pilot to have been of a mindset such that he could have been influenced to change his mind, either immediately before or during the display, and attempt the rolling manoeuvre despite having stated that he would not. It is not known whether this decision was premeditated or impulsive, but in either case the question is raised as to whether the pilot would have benefitted from a more detailed briefing, where the exact sequence of manoeuvres to be performed was clearly specified and agreed. This, combined with flying a practice display, would have reduced the likelihood of the pilot reversing his decision. In contrast to the pilot's previous display in Jersey, this display sequence was not practised beforehand.

Whilst the lead Hurricane pilot and the display sequence organisers were satisfied from the briefings and the pilot of G-HURR's comments that he was clear about the manoeuvres that he would and would not be performing, his action of attempting the rolling manoeuvre suggested otherwise. As the briefings were conducted verbally, no record of them was available. If the display sequence had been clearly defined beforehand, the display organisers could have limited the display to those manoeuvres that both pilots were comfortable to perform.

The following Safety Recommendation is therefore made:

It is recommended that the UK Civil Aviation Authority requires that the sequence of manoeuvres for a flying display is clearly specified in advance of the display and provided to the display organiser and that the sequence is practised prior to displaying to the public.

Safety Recommendation 2009-052

A pilot's DA specifies the category of aerobatics to which he is limited when flying a display, either solo or in a formation. When authorised to fly in a tail chase, there are no aerobatic categories to which a pilot is limited. Therefore the following Safety Recommendation is made:

It is recommended that the UK Civil Aviation Authority amend the Display Authorisation process to identify the level of aerobatic manoeuvres a pilot is permitted to perform when leading or flying as a member of a tail chase. **Safety Recommendation 2009-053**

2.3 Human performance and limitations.

The pilot of G-HURR had demonstrated his ability to perform an aileron roll on previous occasions and knew from experience that he needed to raise the aircraft nose some 40° above the horizon prior to commencing the manoeuvre. However, the Derry turn was not a display manoeuvre which the pilot was known to have used often in solo displays, if at all. It is therefore unlikely that he had ever flown such a manoeuvre before in a tail chase in the Hurricane. His failure to pitch the nose up sufficiently prior to commencing the roll may have been due to a loss of situational awareness, possibly from focusing on the lead aircraft. For possibly the same reason, he does not appear to have been fully aware of his location or his height above the ground. If he was concerned about performing the manoeuvre, or simply felt under pressure, his stress level would have increased significantly and this could also have adversely affected his performance. Had he allowed himself to relax after the display with the Bf 108s, he may have been underaroused at the commencement of the roll. It was not possible to determine which was more likely.

When he rolled inverted, the picture that confronted him was probably different from that which he expected to see; this may be why he stopped the roll. The steeply rising ground ahead towards Lancing Hill may have significantly affected his perception of the aircraft's pitch attitude and would also have reduced the height available for recovery. With the nose dropping rapidly, he would have found himself in a high-stress situation which required him to make a rapid assessment of the situation and initiate the appropriate recovery action. Human performance limitations are such that in a high-stress situation it is often not possible to assess all the relevant factors required to arrive at the correct solution in the limited time available. The action taken, though believed to be correct, may therefore prove to be inappropriate. In this case the pilot appears to have attempted to pull the aircraft through the vertical dive to recover, but there was insufficient height to complete the manoeuvre. There is also the possibility that some form of disorientation contributed to his loss of situational awareness.

Human factors have been a significant causal factor in this and other flying display accidents reviewed in this investigation. The CAA, in its brochure '*Civil Air Displays, a guide for pilots*', contains useful guidance which, if fully adopted, will help to mitigate human performance failures in flying displays. The following Safety Recommendation is therefore made:

It is recommended that the UK Civil Aviation Authority introduce a recurrent programme of Human Factors training for display pilots. The training should specifically address human performance and its limitations when undertaking display flying and should form part of the Display Authorisation process.

Safety Recommendation 2009-054

2.4 Display flying

The review of other display accidents also showed human performance to be the single most common factor. In many accidents entry parameters such as height and speed may have been incorrect, or the technique used for flying a manoeuvre may have been inappropriate. The reasons why experienced pilots allow themselves to arrive in such situations are not clear, but because pilots are not required to have demonstrated specific manoeuvres in order to renew their DA, the erosion of the necessary skills may go undetected.

The pilot of G-HURR renewed his DA on a Jungmeister, which is a Category 'A' aircraft as it has an engine of less than 200 hp. This allowed him to display aircraft in Category 'C', with in excess of 600 hp, such as the Hurricane. Furthermore, there was no requirement for him to practise in the display discipline, in this case, the tail chase. The following Safety Recommendation is therefore made:

The UK Civil Aviation Authority should amend CAP 403 to require a pilot to demonstrate competence in each aircraft category to be flown and the level of aerobatic maneuvers to be performed in the specific flying display discipline (solo, formation, tail chase) for which the Display Authorisation is being sought.

Safety Recommendation 2009-055

2.5 Organisational control issues

The operator's Organisational Control Manual contained all the relevant information that the operator and pilot required to operate the aircraft safely. The DA determines the type categories and limitations to which a pilot

may operate. The training element of the OCM provided a mechanism for the operator and pilots to identify the limitations which may be agreed or imposed on individual pilots. However there was no record that these training requirements had been complied with in this case. The following Safety Recommendation is therefore made:

It is recommended that the UK Civil Aviation Authority (CAA) remind CAP 632 aircraft operators of the need to clearly identify in the Organisational Control Manual the level of initial and recurrent training required and that the CAA should ensure compliance with those requirements. **Safety Recommendation 2009-056**

2.6 Regulatory oversight

The CAA, with the support of the display flying industry, has developed a workable structure of legislation and guidance. A balance has to be struck between safe regulation and avoiding unreasonable additional costs, above the already considerable expense of operating historic aircraft. The large numbers of the public who attend the airshows and the enthusiasm they have for the historic aircraft displays is a testimony to their importance. The guidance material in CAP 632 and CAP 403 represents a strong framework for operators to work within.

The last CAA review of display flying was carried out in 1996/7 and delivered a significant number of recommendations that were implemented. In order to maintain acceptable safety standards of display flying it would seem appropriate for the CAA to continue to conduct such safety reviews periodically. The following Safety Recommendation is therefore made:

It is recommended that the UK Civil Aviation Authority conduct periodic reviews of the current operating requirements to ensure that they provide adequate safety for display flying. **Safety Recommendation 2009-057**

3 Conclusions

(a) Findings

- 1 The aircraft had a current Permit to Fly and was properly maintained.
- 2 No evidence was found of any defect or malfunction in the aircraft that could have caused or contributed to the accident.
- 3 The mass and centre of gravity of the aircraft were within the prescribed limits.
- 4 The pilot was properly licensed, held a current Class 2 medical certificate and was properly authorised to display the Hurricane.
- 5 There was no record of the pilot having completed the currency training requirements as specified in the operator's Organisational Control Manual.
- 6 The pilot appears to have attempted to perform a rolling manoeuvre with insufficient nose-up pitch attitude to ensure safe completion of the manoeuvre in the height available.
- 7 When the roll stopped at the inverted, the aircraft's nose dropped rapidly and insufficient height was available to recover from the dive.
- 8 The pilot had stated on a number of occasions prior to the display that he would not be rolling the aircraft, but in the event, did so.
- 9 Whilst the lead Hurricane pilot and the display sequence organisers were satisfied from the briefings and the pilot of G-HURR's comments that he was clear about the manoeuvres he would be performing, his action of attempting the rolling manoeuvre suggested otherwise.
- 10 The intended display sequence had not been practised.
- 11 The pilot had not demonstrated similar manoeuvres in an aircraft in the same category when his Display Authorisation was last renewed.

(b) Causal factors

- 1 The accident probably occurred as a result of the pilot attempting an unplanned rolling manoeuvre.
- 2 When the manoeuvre was commenced, the airspeed was adequate, but the nose-up pitch attitude was insufficient to enable the manoeuvre to be completed safely in the height available.
- 3 When the roll stopped in the inverted position, the aircraft's nose dropped rapidly and there was insufficient height available for the recovery manoeuvre the pilot attempted.

4 Safety Recommendations

- 4.1 Safety Recommendation 2009-052:** It is recommended that the UK Civil Aviation Authority requires that the sequence of manoeuvres for a flying display is clearly specified in advance of the display and provided to the display organiser and that the sequence is practised prior to displaying to the public.
- 4.2 Safety Recommendation 2009-053:** It is recommended that the UK Civil Aviation Authority amend the Display Authorisation process to identify the level of aerobatic manoeuvres a pilot is permitted to perform when leading or flying as a member of a tail chase.
- 4.3 Safety Recommendation 2009-054:** It is recommended that the UK Civil Aviation Authority introduce a recurrent programme of Human Factors training for display pilots. The training should specifically address human performance and its limitations when undertaking display flying and should form part of the Display Authorisation process.
- 4.4 Safety Recommendation 2009-055:** The UK Civil Aviation Authority should amend CAP 403 to require a pilot to demonstrate competence in each aircraft category to be flown and the level of aerobatic maneuvers to be performed in the specific flying display discipline (solo, formation, tail chase) for which the Display Authorisation is being sought.
- 4.5 Safety Recommendation 2009-056:** It is recommended that the UK Civil Aviation Authority (CAA) remind CAP 632 aircraft operators of the need to clearly identify in the Organisational Control Manual the level of initial and recurrent training required and that the CAA should ensure compliance with those requirements.
- 4.6 Safety Recommendation 2009-057:** It is recommended that the UK Civil Aviation Authority conduct periodic reviews of the current operating requirements to ensure that they provide adequate safety for display flying.

Appendix A**Extract from ANO Article 80 and relevant CAA Publications**

A pilot's obligations under Article 80 of the Air Navigation Order (ANO) 'Flying displays' are described as follows:

- '(2) The commander of an aircraft who is-*
- (a) intending to participate in a flying display shall take all reasonable steps to satisfy himself before he participates that-*
 - (i) the flying display director has been granted an appropriate permission under paragraph (5);*
 - (ii) the flight can comply with any relevant conditions subject to which that permission may have been granted; and*
 - (iii) the pilot has been granted an appropriate pilot display authorisation; or*
 - (b) participating in a flying display for which a permission has been granted shall comply with any conditions subject to which that permission may have been granted.*
- (3) No persons shall act as pilot of an aircraft participating in a flying display unless he holds an appropriate pilot display authorisation and he complies with any conditions subject to which the authorisation may have been given.'*

The event organiser, referred to in Article 80 as the 'display director' must comply with Article 80 (4) which states:

- '(4) The flying display director shall not permit any person to act as pilot of an aircraft which participates in a flying display unless such person holds an appropriate pilot display authorisation.'*

Appendix A

The powers available to the CAA and requirements placed upon them are set out in Article 80, paragraphs 5 and 6 of which state:

‘(5) The CAA-

- (a) shall grant a permission required by virtue of paragraph (1) if it is satisfied that the applicant is a fit and competent person, having regard in particular to his previous conduct and experience, his organisation, staffing and other arrangements, to safely organise the proposed flying display;*
- (b) may grant such a permission subject to such conditions, which may include conditions in respect of military aircraft, as the CAA thinks fit.*

(6) The CAA shall, for the purposes of this article-

- (a) grant a pilot display authorisation authorising the holder to act as pilot of an aircraft taking part in a flying display upon it being satisfied that the applicant is a fit person to hold the authorisation and is qualified by reason of his knowledge, experience, competence, skill, physical and mental fitness to fly in accordance therewith and for that purpose the applicant shall furnish such evidence and undergo such examinations and tests as the CAA may require; and*
- (b) authorise a person to conduct such examinations or tests as it may specify.’*

Appendix A**Relevant CAA Publications**

In order to ensure compliance with the legislation, the CAA has produced two ‘guidance’ documents. One deals with the operation of ex-military aircraft and the other with flying displays.

Civil Aviation Publication 632, ‘Operation of ‘Permit-to-Fly’ Ex-Military Aircraft on the UK Register’ specifies the operational requirements that an applicant must meet before a Permit-to-Fly can be issued. The applicant could be an organisation or individual and the CAP covers ex-military aircraft with a Maximum Take-off Weight Authorised (MTWA) in excess of 2,730 kg. The applicant must submit an OCM to the CAA for acceptance, setting out the manner in which they will comply with CAP 632 and manage their operations. During 2007, the CAA regulated 51 operators using a variety of aircraft types under the provisions of CAP 632.

Should an organisation or individual wish to operate an aircraft at flying displays, a second publication, CAP 403 ‘Flying Displays and Special Events: A Guide to Safety and Administrative Arrangements’ provides information on the established requirements and how they can be met.

The CAA also issues a pamphlet, ‘Civil Air Displays, a guide for pilots’. This 18-page document contains valuable information for display pilots on all elements of planning and carrying out a flying display.

Appendix B**BBMF Training and Currency Requirements**

The following information describes the relevant training and currency requirements specified by the RAF Battle of Britain Memorial Flight (BBMF) in respect of the operation and displaying of their historic aircraft, which includes types such as the Hurricane and Spitfire:

Displays

Only set displays are flown, with no variations or permission for pilots to vary manoeuvres or sequences of manoeuvres.

Training

Training is structured to ensure that at the end of April each year, all the BBMF pilots are ready to fly their displays in front of the Air Officer Commanding. He is advised on the safety and quality of the display by the flight commander or another experienced BBMF pilot. Subject to the pilot achieving the required standard, he will be awarded his display authorisation. This authorisation limits the pilot to a set display with no tail chase. Pilots are cleared for tail chasing or mirror manoeuvres in their second season, after specific training to qualify the pilot for those activities. Training records and assessments are maintained.

Currency

During the first season, or up until the pilot achieves 50 flying hours on the BBMF fighters, the pilot must fly either a display or practice display within 10 days. If he does not achieve this, the pilot must perform a practice display to a base of 500 ft, observed by the flight commander, to bring the pilot back into currency. In the second season the period is increased to 14 days instead of 10 days. There is an additional requirement that a pilot must have carried out five landings in a tail wheel aircraft in 30 days, irrespective of whether it is the pilot's first or subsequent season.

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6/2008	Hawker Siddeley HS 748 Series 2A, G-BVOV at Guernsey Airport, Channel Islands on 8 March 2006.	August 2008
7/2008	Aerospatiale SA365N, G-BLUN near the North Morecambe gas platform, Morecambe Bay on 27 December 2006.	October 2008
1/2009	Boeing 737-81Q, G-XLAC Avions de Transport Regional ATR-72-202, G-BWDA, and Embraer EMB-145EU, G-EMBO at Runway 27, Bristol International Airport on 29 December 2006 and 3 January 2007.	January 2009
2/2009	Boeing 777-222, N786UA at London Heathrow Airport on 26 February 2007.	April 2009
3/2009	Boeing 737-3Q8, G-THOF on approach to Runway 26, Bournemouth Airport, Hampshire on 23 September 2007.	May 2009
4/2009	Airbus A319-111, G-EZAC near Nantes, France on 15 September 2006.	August 2009
5/2009	BAe 146-200, EI-CZO at London City Airport on 20 February 2007.	September 2009