ACCIDENT

Aircraft Type and Registration:	Extra EA300L, G-DUKK
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine
Year of Manufacture:	2000
Date & Time (UTC):	19 June 2010 at 1501 hrs
Location:	Methley Bridge, Castleford, West Yorkshire
Type of Flight:	Aerial Work
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	31 years
Commander's Flying Experience:	3,600 hours (of which 70 were on type) Last 90 days - 33 hours Last 28 days - 13 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft flew into the ground during a flying display. The pilot had not followed the display routine that he normally practised and initiated recovery from a flat spin at a height lower than required. The pilot was fatally injured on impact. The engineering investigation concluded that the aircraft was serviceable prior to the accident.

Two Safety Recommendations have been made as a result of this investigation.

History of the flight

On the day of the accident the pilot planned to perform three flying displays. The weather conditions were suitable, although the strong wind would make display flying more challenging. The sequence of manoeuvres, which formed the pilot's display, was written on a card which was kept in a holder on the top of the aircraft instrument panel, where it could be seen easily by the pilot in flight. The manoeuvres, which formed the pilot's display, varied in complexity and included a Muller Tower[1], with a two-turn flat spin, followed by a half cloverleaf. The first two displays were close to Sherburn-in-Elmet, where the aircraft was based, and took place at approximately 1200 hrs without incident.

Footnote

[1] The Muller Tower, Zwilbelturm, or Spiral Tower is attributed to Swiss and European aerobatic champion Eric Muller, who is thought to have invented it in 1974. From a right roll on a vertical up line, a tumble is begun that resembles an inverted ascending spin. The controls are reversed to accomplish a transition to an upright flat spin as the aircraft reaches apogee and starts to descend.

During these displays the pilot appeared to follow the sequence of manoeuvres shown on his display card. The third display was at Methley boatyard, 7 nm south-west of the airfield, and was planned to take place at 1500 hrs.

In the break between the displays the pilot refuelled the aircraft and had a snack with friends; he was observed to be in good spirits and looking forward to the last display, which his family and friends would be attending. He did comment though that he was feeling a little tired, and that the wind had made things a little more difficult for him during his earlier displays. He also sent several text messages with his phone to friends who were aerobatic pilots. In these messages he indicated that he was not happy with all aspects of the displays he had just flown, specifically his Muller Tower manoeuvre. The pilot then returned to his aircraft and was seen to get airborne at around 1450 hrs.

Shortly before 1500 hrs the aircraft performed a flypast and commenced its display at the boatyard. The display started with the aircraft flying past the crowd on its side, a manoeuvre known as a knife-edge pass. It then performed an inverted flypast, during which the pilot could be seen waving to the crowd. The aircraft's subsequent manoeuvres were not in the sequence shown on the pilot's display card. After several standard aerobatic manoeuvres the aircraft performed a vertical manoeuvre which the pilot may have intended to be a Muller Tower. The aircraft fell out of this manoeuvre into a dive, which was followed by the aircraft pulling up to the vertical and rolling right once more. The evidence indicates that this was also intended to be a Muller Tower. The aircraft then made five descending turns in a flat spin before it was seen to recover from the spin into a steep dive. The aircraft was now very low, and it flew into the ground. Witnesses rushed to the scene but it was immediately apparent that nothing could be done to assist the pilot. There was no fire.

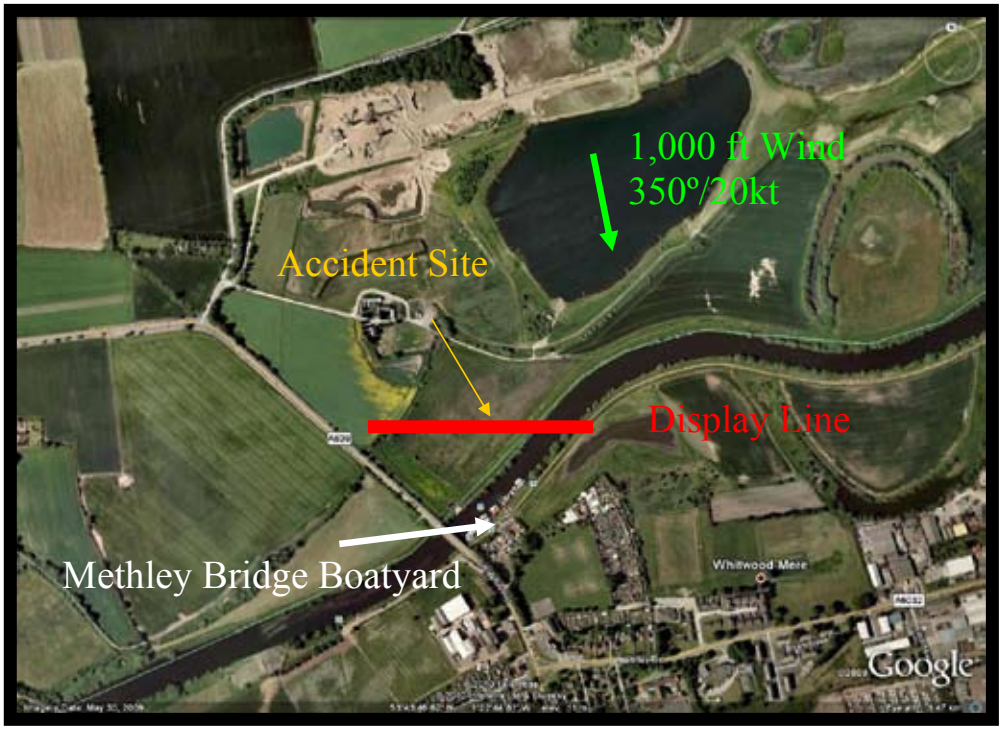

Figure 1

Location of the display line and accident site

Medical and Pathology

The post-mortem report concluded that the pilot died of a severe head injury caused by his head striking the instrument panel of the aircraft when it crashed. The pilot's head struck the instrument panel because his shoulder harness mounting had failed; however, the pathologist considered that the accident may still have proved fatal even if the shoulder harness had not failed. Toxicology revealed no evidence of drugs or alcohol and the carbon monoxide levels found were considered normal.

Witness evidence

There were many witnesses to the accident, and a great deal of photographic and video evidence. Photographic evidence indicates the accident occurred at 1501 hrs.

One witness, who knew the pilot well and had seen his display several times before, commented that the flypasts seemed lower than normal, and that the flat spin was performed at a lower height than normal, the pilot normally performing only two or three turns before recovering.

An analysis of the photographic and video evidence confirmed that, after the inverted flypast, the sequence of the manoeuvres flown was unlike those shown on his display card. Furthermore, the sequence flown was not depicted on any of the pilot's discarded display sequence cards recovered after the accident.

Video and photographic evidence

The National Imagery Exploitation Centre (NIEC) was given 278 photographs and three video clips, taken by witnesses to the accident. The NIEC were asked to ascertain, where possible, the aircraft's height and speed at certain points throughout the Muller Tower manoeuvre. It was unable to identify accurately any speeds for the aircraft before it entered the manoeuvre. It did determine that the aircraft entered the final manoeuvre at a height of 230 ft (+/- 30 ft), and that it reached a maximum height of 1,770 ft (+/-300 ft).

A sequence of photographs showed the aircraft in a flat spin, showing when pro-spin control inputs[2] were removed and the correct spin recovery control inputs (right rudder and neutral aileron) were made (Figure 2). The NIEC established that the aircraft was at a height of 690 ft (± 150 ft) when the spin recovery was initiated.

Aircraft information

The Extra EA300L is a two-seat aerobatic aircraft powered by a 300 hp Lycoming AEIO-540-L1B5 piston engine, driving a three-bladed constant speed propeller. The airframe is of steel-tube construction, and the wings, fin and tailplane are manufactured from composite material. It has a maximum takeoff weight of 950 kg and a V_{NE} of 220 kt. G-DUKK was fitted with an optional smoke system which when activated injects paraffin oil into the exhaust to generate a trail of smoke for display purposes.

Each seat on G-DUKK was equipped with a five-point harness which consisted of two shoulder harnesses, two lap straps and a crotch strap. The two shoulder harnesses of the rear seat were attached to a horizontal steel tube behind and above the rear seat back.

Maintenance history

The aircraft's last maintenance was an annual inspection on 24 May 2010, when the airframe and engine had accumulated 316 hours. No significant maintenance,

Footnote

[2] To maintain the aircraft in a left flat spin, left rudder is held with right aileron.

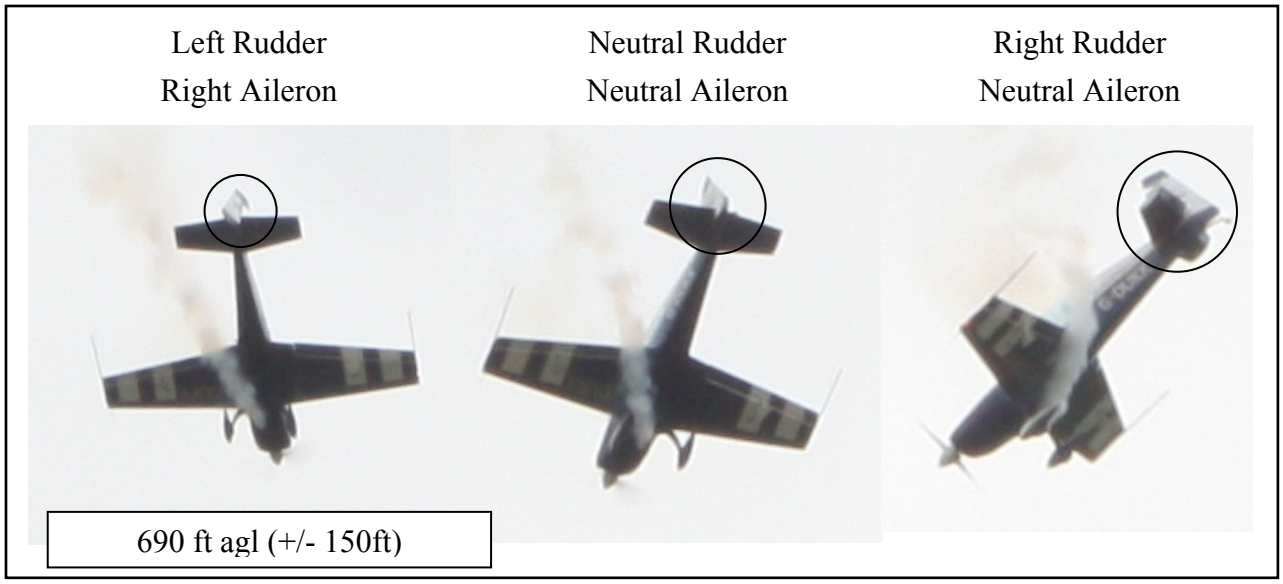

Figure 2

G-DUKK spin recovery initiation from a left turning flat spin
All three pictures taken within one second
(photographs courtesy Paul McCormick)

other than normal annual inspection items, was carried out during this maintenance input.

Accident site and initial wreckage examination

The wreckage of the aircraft was found upright in a flat field of tall grass, approximately 200 m north-east of Methley Bridge, Castleford (Figure 3). The aircraft had travelled a distance of just 3.9 m from its initial impact point to its final resting point, indicating a steep nose down impact, consistent with the video and still imagery. All three propeller blades had separated near their roots indicating that they had a high rotational energy at impact. The steel-tube airframe had sustained numerous overload failures, and the composite wing upper and lower surfaces were destroyed. The empennage had failed in bending overload due to the inertial forces at impact. There was no evidence of any pre-impact separations.

Video evidence of the aircraft just prior to impact revealed that at approximately 100 ft agl it was in a nose-down attitude of -40° (±5°), with a flight path angle of -53° (±5°) and a groundspeed of at least 100 kt (120 ±20 kt). The last available still image of the aircraft (Figure 4) shows the aircraft in a nose-down

Figure 3

Aircraft wreckage – the distance from nose impact point to nose resting point was 3.9 m.

attitude of -25° (±5°) just prior to impact. This image also revealed that the aircraft's smoke system was active until impact.

Detailed wreckage examination

The aircraft wreckage was recovered to the AAIB's facility in Farnborough for a detailed examination. An examination of the flying controls revealed that all failures were consistent with impact loads. There were no disconnections within the systems and no evidence of control restrictions. A detailed examination of the engine was not performed because the propeller had high rotational energy at impact and the video evidence revealed that there was engine noise and smoke up to the point of impact. There was no evidence of any pre-impact structural failures.

The rear seat instrument panel had suffered a severe impact consistent with the pilot's head injuries. This impact had destroyed the altimeter, such that it could not be tested but it was found set to 1019 mb - the correct QNH at the time of the accident. The airspeed indicator (ASI) was tested and found to under-read by 20 to 40 kt (for example, at an airspeed of 190 kt the ASI indicated 160 kt) however, such a large error should have been readily apparent to the pilot so it is probable that the impact disturbed the sensitive mechanical mechanism inside the ASI, thus introducing the error. The transponder was found set to '7000' but had been left in 'standby' mode.

The steel tubular frame above and behind the rear seat, to which the shoulder harnesses were attached, had failed in overload. The rear seat back attachment points had also failed, allowing the seat back to pivot forwards. The lap and crotch straps were still secured.

Figure 4

G-DUKK moments before impact – nose-down pitch angle estimated at 25° (±5°)
(photograph courtesy Paul McCormick)

The fuel selector was found set to the acrobatic[3] fuel tank. It was not possible to establish the quantity of fuel remaining because the fuel tanks had ruptured, but a fuel receipt indicated that the pilot had uplifted 49.7 litres (13.1 USG) prior to the accident flight. The refueller recalled that the pilot would normally fill the acrobatic tank (51 litre capacity) to the top and add 5 litres to each wing tank prior to a display flight. This would have been more than sufficient for the planned flight.

The aircraft load included the pilot (81 kg) and his parachute (7.5 kg). There was no baggage. The basic weight of the aircraft was 686 kg. Calculations showed that with any amount of fuel in the acrobatic tank, any amount of paraffin oil, and up to 10 litres of fuel in the wing tanks, the aircraft's weight and CG would have been within limits for aerobatics.

Footnote

[3] The aircraft manufacturer's Pilot's Operating Handbook uses the term 'acrobatic' to refer to aerobatic.

Crashworthiness regulations and impact g

The EA300 was type certificated to Federal Aviation Requirement (FAR) 23 Amendment 34 (2/1987) which states in section 23.561 under *Structure*, *Emergency Landing Conditions*:

> *'The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when – (1) Proper use is made of the belts or harnesses provided for in the design; and (2) The occupant experiences the ultimate inertia forces shown in the following table:'*

The table which follows states that for an aerobatic category aircraft these ultimate inertia forces are: 4.5 g upward, 9.0 g forward, and 1.5 g sideward. In 1988 Amendment 36 was introduced which required dynamic impact testing to be carried out with anthropomorphic test dummies. Amongst other requirements, a peak deceleration of 26 g needed to be demonstrated (in the forward direction).

The evidence from the accident site revealed that the aircraft had come to rest in a horizontal distance of just 3.9 m. The evidence from the video analysis indicated a final impact speed of at least 100 kt. This would have resulted in an overall deceleration during impact of at least -339 m/s^2, which is equal to 34.6 g. The peak g at impact would probably have been approximately double this value. This is considerably in excess of the 9g certification requirement for the EA300 and also in excess of the current 26g requirement for emergency landing conditions.

Meteorology

On the day of the accident there was an area of high pressure to the west of the UK, which maintained a northerly flow over Yorkshire. At 1500 hrs, in the area of the accident, the wind at 2,000 ft was from the north at 23 kt. At 1,000 ft the wind was 20 kt, and the surface wind was from the north at 17 kt. The surface wind remained stronger than would normally be expected because of a funnelling effect that occurs in that area when there is a northerly flow. The wind speeds recorded at 1500 hrs were approximately 5 kt lower than the wind speeds recorded at the time of the earlier displays. The visibility was more than 10 km and there were no clouds below 4,000ft.

Observation of the spin recovery manoeuvre

The investigation observed a sortie in an Extra EA300L which focused on the Muller Tower manoeuvre and the height required to recover the aircraft from a flat spin. The test aircraft entered the manoeuvre at a height of 4,000 ft at 180 kt. The aircraft achieved a maximum height of 5,400 ft and after five turns in a flat spin, passing 4,600 ft, the spin recovery was initiated. The aircraft achieved level flight at 3,600 ft, 1,000 ft below the height at which the recovery was initiated. Several more recoveries from a developed flat spin were flown, in which the aircraft consistently required 1,000 ft to recover to level flight.

Pilot information.

The pilot gained a PPL in December 1999. He was issued with a commercial pilot's licence in June 2003 and an instructor rating shortly after that. In March 2008, after attending an aerobatics course, the *'No Aerobatics'* limitation was removed from his instructor rating and in April 2008 he gained an ATPL (Aeroplanes). Around that time he started to fly aerobatics in G-DUKK. In June 2009 he was issued with a Display Authorisation (DA) for unlimited aerobatics to a minimum height of 300 ft, and flypasts to a minimum height of 100 ft. In

the remainder of 2009 the pilot flew at three organised displays. At the end of 2009 G-DUKK was sold and the pilot had no access to an aerobatic aircraft until April 2010, when the new owner of G-DUKK decided he would leave it at Sherburn-in-Elmet and gave his permission for the pilot to continue to fly, and display, his aircraft. The pilot then resumed practising his display routine and had flown the aircraft approximately 20 times since the change in ownership. The pilot's first public displays of the 2010 season were on the day of the accident.

The pilot worked as an airline pilot, and had been flying a part-time roster over the winter. He had not flown for the airline for a period of about six weeks until six days before the accident when he returned to a full-time roster. His first week back had consisted of three early starts, followed by a Licence Proficiency Check and an Operator Proficiency Check which were carried out over two days in a simulator near Manchester. The Type Rating Examiner who conducted the simulator check commented that the pilot had performed well. The available evidence indicated that, in the week prior to the accident, the pilot practised his display in G-DUKK at least five times. However, these practices were not observed by any of his colleagues who had aerobatic experience.

Display flying

The rules governing the conduct of civil air displays in the United Kingdom are given in the Air Navigation Order (ANO), '*The Rules of the Air Regulations'*. CAP 403 – '*Flying Displays and Special Events: A Guide to Safety and Administrative Arrangements*', published by the CAA, is, according to its introduction:

> *'intended as a code of practice and an indicator of best practice to provide guidance to ensure that the safety of both the participants and the spectators is not compromised.'*

Further guidance is given to display pilots in CAA Document No 743.

Civil flying displays within the United Kingdom are regulated by Article 162 of the ANO. When a flying display is at an advertised event, open to the public, Article 162 places responsibilities on both the organiser of the flying display (the Flying Display Director) and the participating pilots. For such an event the Flying Display Director must obtain the permission in writing of the CAA, and civil display pilots must hold a Display Authorisation (DA). At small flying displays - three individual displays or less - the pilot of a participating aircraft may act as the Flying Display Director. For the display at Methley Bridge the pilot was also acting as the Flying Display Director.

Before a Permission can be issued, the CAA must be satisfied that:

> *'A person is fit and competent as a Flying Display Director, having regard in particular to his previous conduct and experience, his organisation, staffing and other arrangements, to safely organise the proposed Flying Display.'*

Similarly, a pilot must satisfy the CAA that:

> *'He is a fit person to hold a DA and is qualified by reason of his knowledge, experience, competence, skill, physical and mental fitness.'*

To this end, the pilot is required to provide such evidence and undergo such tests and examinations as the CAA may require. In practice the CAA authorises certain people to conduct these tests on its behalf. These people are known as Display Authorisation Evaluators (DAEs). The CAA will normally refer any pilot who is seeking a DA to a DAE in his discipline and area.

For aerobatic DAs the DAE will assess the experience and the performance of the potential display pilot and recommend them for a specific category of aerobatic DA, depending on their experience. The categories are, by increasing complexity of manoeuvre, Standard, Intermediate, Advanced and Unlimited. There are no restrictions on the aerobatic figures, including autorotative figures, which a pilot flying in the '*Unlimited*' category may perform. If a pilot can perform only one or two aerobatic manoeuvres from a particular category, the pilot can be recommended for a lower category, but with the specific manoeuvres that the pilot can fly in the higher category approved individually. The DAE will also recommend a minimum height for the manoeuvres to be carried out.

On 24 June 2009, the accident pilot was assessed for a DA for the first time. The DAE recommended him for an Unlimited DA, with a minimum height of 100 ft agl for flypasts and aerobatics. On 29 June 2010 the CAA accepted the DAE's recommendation, but increased the minimum height for aerobatics to 300 ft, and issued the pilot with an Unlimited DA.

During the investigation the AAIB spoke to several DAEs who were approved to authorise aerobatic DAs. None witnessed the assessment of the accident pilot for his DA and could not therefore offer comment on his individual suitability for a particular category of DA. Nevertheless, they all expressed surprise, given the accident pilot's relative inexperience of unlimited aerobatics, that he had been given the '*Unlimited*' category of aerobatics for his first DA.

Human factors

The investigation consulted a human factors expert to explore why the pilot had not followed the planned display routine, and why he held the aircraft in a flat spin for five turns instead of his more usual two or three turns. His report included the following:

'The fact that he chose to pursue aerobatics and display flying suggests that he was probably relatively extraverted. This can be associated with impulsivity.

The aerobatics restriction on his Flying Instructor's licence was removed in 2008 and he received his display authorisation less than a year before the accident. That authorisation was endorsed as 'Unlimited'. The effect of this endorsement can only be guessed at. However, it was unlikely to be seen as counselling caution or the need for supervision, particularly if applied to an already confident individual. As such, it might exacerbate the effects of impulsivity.

Some cumulative fatigue and life stress may have played a part. The wind on the day was difficult; perhaps that played a part. An independent assessment of his performance and advice from a more experienced performer either on 19 June or during the preceding week might have helped the pilot overcome his difficulties or decide that he was not yet ready for the display. Such advice would be especially valuable if he was, indeed, an extravert and impulsive person as suggested. The granting

of a Display Authorisation appropriately and necessarily involves an assessment of skill in flying aerobatics. A failure of skill is, however, less likely to be the root cause of a display flying accident than a failure of judgement. Judgement is harder to assess. It may be worthwhile considering a Display Authorisation process that requires an element of mentoring and supervision until a reasonable amount of experience has been accrued. This requirement, of itself, might induce some caution in newly authorised pilots.'

Analysis

The examination of the aircraft wreckage did not reveal any problems with the flight control system and this was consistent with the photographic evidence, which revealed that the rudder and elevator were being moved as expected during the spin and during the recovery. There were no pre-impact separations or other defects that might explain a failure of the aircraft to recover from a spin, and the engine appeared to have been producing power prior to impact.

The pilot departed from the routine shown on his display card after two flypasts. CAP 403 states:

'The impromptu, ad hoc, unrehearsed or unplanned should never be attempted.'

The pilot's DA approved a minimum aerobatic display height of 300 ft. Flight observations in a similar aircraft showed consistently that 1,000 ft was required to recover the aircraft to level flight from a flat spin. Therefore, to achieve this, the pilot would have needed to initiate the recovery from the spin at a height of 1,300 ft. Photographic evidence indicated that the recovery was initiated at 690 +/-150 ft agl. From this height flight observations indicated a safe recovery would not have been possible.

The human factors expert considered that the pilot's judgement may have been affected by fatigue and life stresses. He also considered that any tendency the pilot may have had towards impulsive behaviour was unlikely to have been checked by him being awarded the highest category of aerobatic DA at his first assessment.

The pilot suffered a fatal head injury when the tubular structure retaining his shoulder harness failed and his head struck the instrument panel. However, the impact loads were significantly in excess of the certification requirements for the pilot restraint system. The pilot was wearing a headset but no helmet. It is possible that had he been wearing a helmet, the severity of his head injury would have been reduced, but it was not possible to determine whether this would have been to a degree sufficient to alter the fatal outcome. Furthermore, the main impact was to the pilot's forehead, and in an area for which most flying helmets do not provide impact protection.

Safety Recommendations

The DA process was followed correctly, but the existing guidance to DAEs given in CAP 403 did not preclude a relatively inexperienced pilot being awarded an Unlimited category authorisation on first assessment for an aerobatic DA. There may be circumstances in which this would be appropriate, but the forgoing discussion suggests that it should not be the norm. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2010-001

It is recommended that the Civil Aviation Authority amend CAP 403 to advise that only in exceptional circumstances should a pilot be authorised to conduct aerobatic displays in the Unlimited category upon first assessment for an aerobatic display authorisation.

The accident pilot had not had an experienced colleague critique his flying display, or any of his practices, during the 2010 season. The human factors expert considered that a process that requires an element of mentoring and supervision until a reasonable amount of experience has been accrued may help a pilot improve his judgement. Therefore the following Safety Recommendation is made:

Safety Recommendation 2010-002

It is recommended that the Civil Aviation Authority consider introducing a mentoring process for pilots who have received their first Display Authorisation.